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Analysis of methods for assessing the condition of surveyed facilities in Taraz City

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Abstract. Due to the high demand for technical inspection services for buildings and structures, new equipment designed for use in certain conditions appears on the market. On this basis, this article is devoted to the analysis of existing devices and equipment for technical inspection of buildings and structures. The analysis of equipment was carried out during the survey of 8 facilities of Novozhambyl phosphorus plant in Taraz city. In the analysis devices for non-destructive method of strength measurement were used. Based on the results obtained during the tests, the analysis was carried out. Thus, the device UKS MG4 showed the greatest deviation in the measurements when testing the reinforced concrete structures than the devices IPS MG4 and sclerometer. When controlling the reinforcement of reinforced concrete structures by electromagnetic method, the greatest accuracy of measurements showed the device Elcometer 331. The UTM-MG4 device showed a smaller error in measurements compared to a similar A1208 device. As a result of a comparative analysis of devices for determining the humidity of building materials Testo 606 showed a more reliable data, due to a different principle of operation relative to similar devices.
Keywords: technical inspection, concrete strength, non-destructive testing, comparative analysis, material strength.

1. Introduction

The development of construction in the Republic of Kazakhstan provides an increase in the number of buildings and structures erected every year in major cities of Kazakhstan [1]. In the process of their erection and further operation there is a demand for services in the field of expert activities to assess the current technical condition of buildings, inspection of buildings [2]. Such services are also required for buildings constructed in the last century. The demand for such services ensures the continuous development of the field of technical inspection of buildings and structures, which in turn leads to the appearance of new high-precision methods and devices in the market [3–6]. Some methods and devices may be relevant for specific types of structures, while others are universal [7–9]. For this reason, companies involved in technical inspection of buildings and structures are faced with the question of the best choice of one or another method and device. Also, for inspection of complex modern buildings, in view of the customer's desire to reduce stripping operations and stricter requirements for these works, it is necessary to choose the most effective methods of assessment of the inspected objects condition. The high demand for technical inspection services, as well as the inevitable obsolescence of buildings and structures make the chosen topic of this article relevant.

Based on the problems, the purpose of this article is to analyze and improve the existing methods for assessing the condition of buildings under inspection.

The object of the study are methods and instruments designed to carry out technical inspection of buildings and structures of administrative value.

In order to achieve the goal of the article, the following tasks were set and carried out:

1. Analysis of methods for assessing the technical condition of objects;

2. Analysis of non-destructive testing instruments used;
3. Analysis of survey objects in Taraz;
4. Assessment of the possibility of applying new technologies;
5. Performing theoretical research;
6. Performing experiments at construction sites in Taraz.

2. Methods

When assessing the current technical condition of the structural elements of the surveyed buildings the following operations are performed [10]: the properties of structures are determined, possible damages and defects are found, the technical condition is assessed according to categories with the possibility of their subsequent operation according to their functional purpose (as originally intended, or with changes).

To assess the current technical condition, it is necessary to compare the maximum allowable parameters of strength and deformability with the actual parameters, which are determined by the results of the survey. The calculated and normative values for the first and second groups of limiting states, respectively, are taken into account.

Figure 1 shows the principle model of the technical inspection.

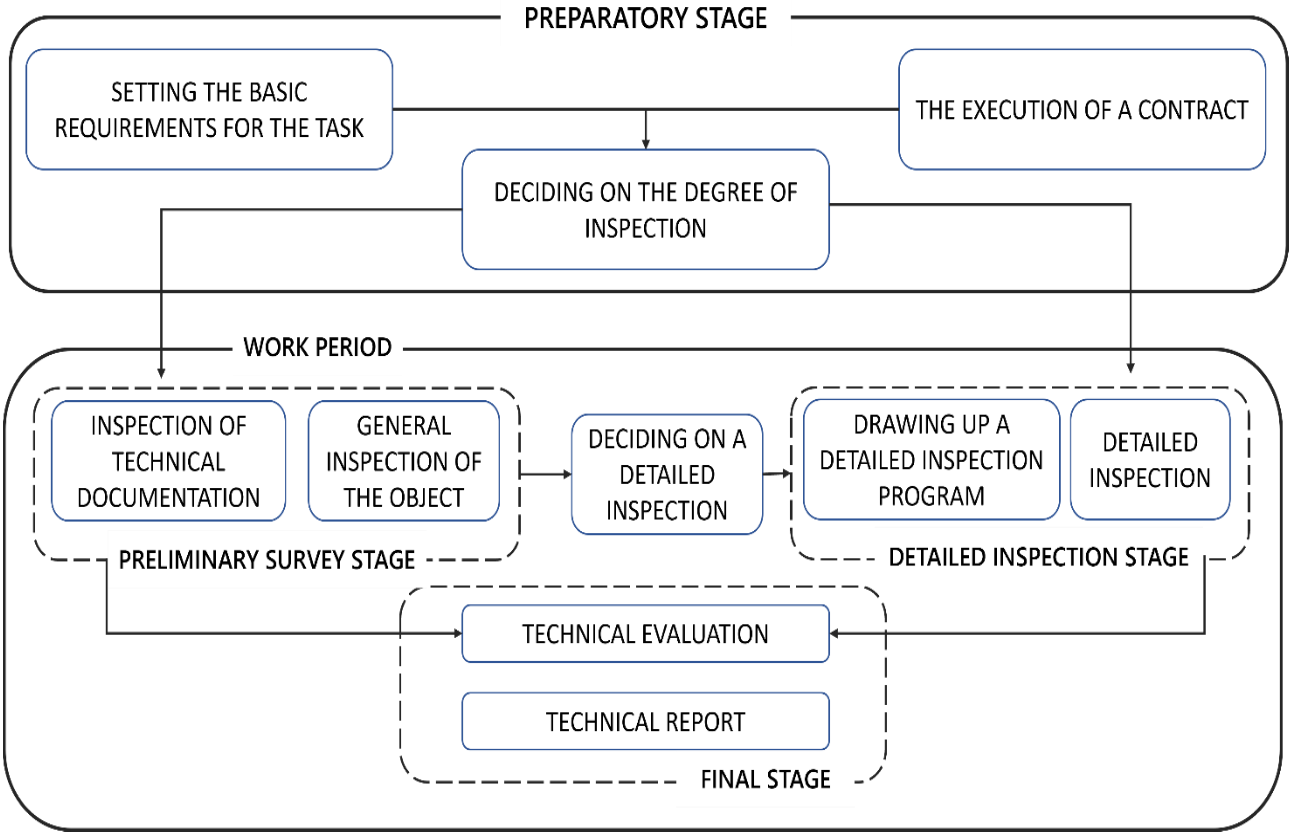


Figure 1 – Principle model of technical inspection

In the course of preparation for the survey, taking into account the agreed methodology of work performance, a preparatory stage, during which the familiarization with the objects, analysis of the available documentation, preliminary inspection, visual inspection of potentially defective areas is carried out. At the end of this stage, the need for further detailed instrumental inspection and the degree of its accuracy are established. At the next stage (detailed instrumental inspection) we make a precise methodology of work performance, calculate the number of necessary autopsies and laboratory tests and immediately the stage of survey works performance. In conclusion, on the basis of all the data obtained at the final stage, a report is prepared and recommendations for further operation are given.

The following types of structures can be subjected to survey works: wooden, steel, masonry structures, concrete and reinforced concrete.

The main criteria for assessing the current condition of reinforced concrete structures are their geometric dimensions, parameters, cracks in local areas, local cracking, nature of cracks (force, non-force), the width of their opening, the thickness of the protective layer of concrete, deformability, criteria of corrosion deterioration.

The main criteria for assessing the current condition of steel structures are: steel defects, the degree of wear of joints of steel frame elements of buildings, corrosion wear, deformability, chemical and mechanical parameters of steel, bends out of plane, displacements from the design position.

The main criteria for assessing the current state of wooden structures are: the identified defects, the presence of cracking zones, the presence of moisture zones, the presence of condensation, atmospheric effects, control of strength parameters of wood used in the manufacture of elements, as well as the quality of processing elements.

2.1 Analysis of methods for assessing the technical condition of the surveyed facilities

The main purpose of the analysis is to collect and prepare the initial materials, and then analyze the methods for assessing the technical condition of the structure of the surveyed objects for the following purposes:

– Comparative analysis of the results of the IPS MG4 [11], Sclerometer [12] and UCS MG4 [13, 14] devices for determining the strength of reinforced concrete structures.

– Comparative analysis of the results of the UCS MG4 and PULSONIC 58-E4900 [15] devices for determining the depth of cracks in reinforced concrete structures.

– Comparative analysis of the results of devices for determining the thickness of metal structures A1208 and UTM-MG4 [14].

– Comparative analysis of the results of devices for determining the humidity of building materials MG4D and Testo 606 [16].

– Advantages of the ultrasonic flaw detector A1220 MONOLITH [17] in estimating the technical condition of concrete and reinforced concrete structures.

Experimental analysis was carried out in Shop №5 of Novodzhambul phosphate plant in Taraz:

- Survey object №1 – Furnace Shop №2.
- Survey object №3 – Domestic Building №2.
- Survey object №4 – Electrode clay preparation department with storage.
- Survey object №5 – Slag dewatering bunkers of the granulation department.
- Survey object №6 – Transshipment node №6.
- Survey object №7 – Gallery №24.

2.1.1 Survey object №1

The building of the furnace shop №2 (Figure 2a) is a rectangular shape in plan with dimensions in the axes 199.25 x 65.0 m. The foundation of the building is monolithic reinforced concrete cupola type under each column separately. The main columns of the framework metal welded I-beam section. Monolithic reinforced concrete floor slabs of the building are made on the technology of permanent formwork. The bearing structures of floor slabs are metal girders of the frame. The frame girders are welded I-beams. Covering slabs are designed of precast ribbed reinforced concrete slabs. The bearing structures of the building's coverage are metal trusses. The building has a skylight. The envelope structures are single-layer wall panels and profiled sheets. Along the length of the building provides for window blocks in five rows in height. Around the building provides four fire escape stairs and two external staircases for access to the walkways on the outer perimeter of the building.

2.1.2 Survey object №2

Domectic building №2 (Figure 2b) is a rectangular shape in plan with dimensions in the axes 96.5 x 18.0 m. The building has four floors. The foundation of the building is monolithic reinforced concrete cupola type under each column separately. The walls of the basement monolithic reinforced concrete. The columns of reinforced concrete monolithic. The floor slabs are prefabricated hollow-core slabs. The bearing structures of the floor slabs are reinforced concrete girders of the frame. The floor slabs are of prefabricated hollow-core slabs. The envelope structures are single-layer wall panels. Along the length of the building is provided for window units.

2.1.3 Survey object №3

The building of the electrode clay preparation department (Figure 2c) consists of two blocks: the production part and the administrative building. The building is rectangular in plan with dimensions in the axes 18.0 x 90.5 m. The size of the industrial part in the axes is 78.0 x 18.0 m, household building 12.0 x 18.0 m. Between the blocks there is a 500 mm axial expansion joint.

The structural solution of the bearing frame of the production part is metal columns and metal trusses. Prefabricated reinforced concrete ribbed cover slabs are adopted as the cover structure.

The structural solution of the residential building is a reinforced concrete frame of precast columns, beams and slabs.

The roofing of the industrial part and the household building is flat from roll-up materials.

The walls of the industrial part of the building are constructed of expanded clay lightweight concrete wall panels of series 1.432-5 240 mm thick, the walls of the consumer building of expanded clay lightweight concrete panels according to series IIR-04. Brick sections of the outer walls are made of red brick, grade M75 on M50 mortar, 380 mm thick.

2.1.4 Survey object №4

In the granulation department (Figure 2d) there are two separately standing slag dewatering hoppers. Structures of slag dewatering bunkers are rectangular in plan with dimensions in axes 14.0x34.5 m each. The walls of bins are designed of monolithic reinforced concrete. Slabs of floor - monolithic reinforced concrete.

2.1.5 Survey object №5

Transshipment node №6 (Figure 2e) has a rectangular shape in plan with dimensions in the axes of 18x24 m. It has one floor and a basement. The functional purpose of Transshipment node №6 is to reload raw materials from gallery №24 to gallery №26.

The structural solution of the structure is a reinforced concrete frame made of columns, beams and trusses. The roof is made of precast reinforced concrete ribbed slabs on precast reinforced concrete trusses. The roof of the building is double pitch with a non-organized drain of roll materials. The foundations of the building are reinforced concrete. Enclosing structures of the gallery are profiled sheets.

2.1.6 Survey object №6

The structure (Figure 2f) is a ground overpass with enclosing structures. Gallery №24 has a total length in axes of ~60.7 m. The structure has one floor. Inside the gallery there are belt conveyors for transporting raw materials. The functional purpose of gallery № 24 is to transport raw materials from the charge department to the Transshipment node №6.

The structural solution of the structure is a reinforced concrete frame made of columns, beams and trusses. The structure of the cover is made of precast reinforced concrete ribbed slabs on precast reinforced concrete trusses. The roof of the building is double pitch with a non-organized drain of roll materials. The foundations of the building are reinforced concrete. Enclosing structures of the gallery are profiled sheets.

Figure 2 – General views of objects at the time of the technical survey:
a – Furnace Shop №2; b – Domestic Building №2; c – Electrode clay preparation department with storage; d – Slag dewatering bunkers of the granulation department; e – Transshipment node №6; f – Gallery №24

4. Results and Discussion

Based on the results of the technical inspection of the listed facilities, the following tables of instrument measurements were compiled.

4.1 Results of the survey of object №1

Table 1 shows the concrete strength values based on the results of nondestructive testing.

Table 1 – Concrete strength values based on the results of nondestructive testing

Structures/defects	Device results IPS MG4	Device results Sclerometer	Device results UCS MG4
Average values of foundation strength	39.6 MPa	37.4 MPa	42.2 MPa
Average strength values of columns	38.6 MPa	36.5 MPa	45.8 MPa
Average strength values of trusses	40.2 MPa	38.5 MPa	44.1 MPa
Average values of the strength of pavement slabs	37.8 MPa	36.1 MPa	39.6 MPa

According to the results, the device UCS MG4 shows more than the sclerometer, by 15-38% and IPS MG4 by 10-35%. The IPS MG4 instrument gives results greater than the sclerometer by up to 10%.

Tables 2 and 3 show the results of measurements and the results of the instruments of nondestructive testing of the protective layer of concrete of the frame and frame columns.

Table 2 – Measurement results and results of non-destructive testing of the protective layer of concrete of the frame and framework columns

Columns of a half-timbered house	IPA MG4 results, mm	Elcometer 331 results, mm

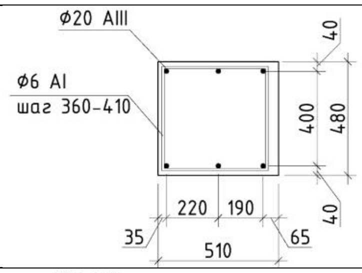
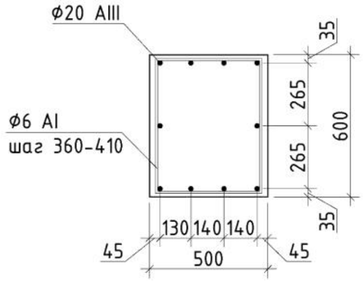
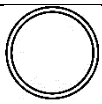
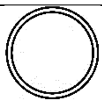
	48 (18)	53 (20)
	31 (20)	35 (20)

Table 3 – Measurement results and results of non-destructive testing of the protective layer of concrete of the frame and framework columns

Metal columns	Thickness gauge results A1208, mm	Results of the thickness gauge UTM-MG4, mm
 Columns KM1 - KM17	8.06	8.02
 Columns KM18 – KM36	6.04	6.01

According to the results of measurements of the thickness of metal columns (pipes), ultrasonic thickness gauge UTM MG4 showed an error of 0.25%, and the device A1208 with an error of 0.5%.

4.2 Results of the survey of object №2

Concrete strength of the structures was determined by non-destructive shock-pulse method using IPS-MG4 device and Digital rebound test hammer, as well as by means of UCS MG4 device. Depth of surface cracks was determined using UCS MG-4 device and PULSONIC 58-E4900 (Figure 3). Ultrasonic scanning was performed with the device MONOLITH A1220.

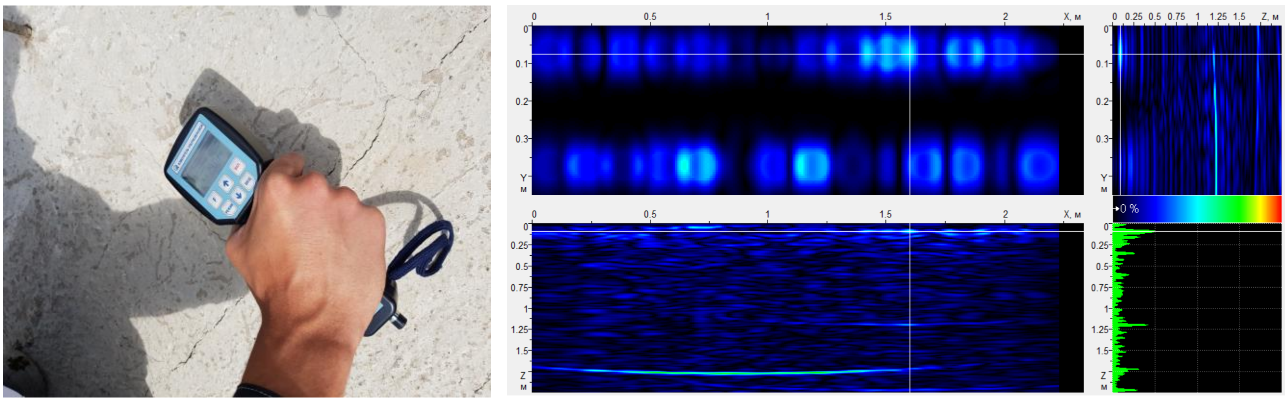


Figure 3 – Flaw detection results processed in Planevisor 4.0

The results of the flaw detector showed that closer to the surface (up to 12 centimeters) there are loose concrete.

Table 4 shows the concrete strength values based on the results of nondestructive testing.

Table 4 – Concrete strength values based on the results of nondestructive testing

Structures/defects	Device results IPS MG4	Device results Sclerometer	Device results UCS MG4
Foundation	15.6 MPa	14.3 MPa	19.4 MPa

According to the results, the device UCS MG4 shows more than the sclerometer by 35% and IPS MG4 by 25%. The result of the IPS MG4 device is greater than the sclerometer by 10%. Table 5 shows the results of the instrumental survey to determine the width and depth of cracks.

Table 5 – Results of instrumental examination to determine the width and depth of cracks

Construction	Crack No.	Width, mm	PULSONIC 58-E4900 depth results, mm	Depth results UCS MG4, mm
Floor slab at +9.230, thickness 250 mm	1	0.2	281	122
	2	0.2	253	113
	3	0.2	245	120
	4	0.1	278	103
	5	0.2	238	113
	6	0.2	265	102

UCS MG4 shows such results only when a lot of pressure is applied to it, at normal pressure the device does not show anything. This is characterized by the fact that the length of the measurement base at the surface sounding of the device 120 mm.

4.3 Results of the survey of object №3

According to the results of the survey, it was found that, in general, the load-bearing capacity of the frame structures is ensured (Table 6).

Table 6 – Values of concrete strength by the results of nondestructive testing by devices IPS-MG4.01 and UCS-MG4S

Pit	Construction	Actually obtained result, MPa	Actually obtained result, MPa
1	Foundation beam	49.8	42.0
	Floor joist	43.3	40.8
	Pile 1	47.1	59.1
	Pile 2	46.5	58.7
2	Foundation beam	52.2	48.2
	Floor joist	47.6	41.3
	Pile 1	43.1	45.8
	Pile 2	47.4	48.3
3	Foundation beam	53.7	46.1
	Pile 1	48.9	58.0
	Pile 2	45.5	57.3

According to the results, the device UCS MG4 shows with an error of ±25% than IPS MG4.

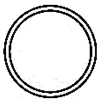
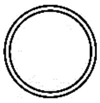
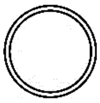
4.4 Results of the survey of object №4

Table 7 shows the values of concrete strength according to the results of nondestructive testing. Table 8 shows the results of measuring the thickness of pipes (metal columns).

Table 7 – Concrete strength values based on the results of nondestructive testing

Constructions/defects	Device results IPS MG4	Device results Sclerometer	Device results UCS MG4
Average strength values of pylons	20,5 MPa	19,5	24,2 MPa
Average strength values of precast props	36,6 MPa	35,1	29,3 MPa

Table 8 – Results of thickness measurement of pipes (metal columns)

Metal columns	Thickness gauge results A1208, mm	Results of the thickness gauge UTM-MG4, mm
 Ø1020x8	8,07	8,02
 Ø820x8	8,06	8,01
 Ø426x6	6,0	6,01

According to the results of measurements of the thickness of metal columns (pipes), ultrasonic thickness gauge UTM MG4 showed an error of 0.25%, and the device A1208 with an error of 0.5%.

4.5 Results of the survey of object №5

Table 9 shows the results of moisture measurement with the MG4 and testo 606.

Table 9 – Results of moisture measurement with MG4 and Testo 606

Metal columns	Thickness gauge results A1208, mm	Results of the thickness gauge UTM-MG4, mm
Rafters	14	18
Cover slab	40	35
Plastering	3	5

The difference between the results of the devices 13-22%, the reason for such results may be that the moisture meter MG4 is a surface moisture meter, and the moisture meter Testo 606 internal.

4.6 Results of the survey of object №6

Table 10 shows the values of concrete strength by the results of nondestructive testing.

Table 10 – Concrete strength values based on the results of nondestructive testing

Structures/defects	Device results IPS MG4	Device results Sclerometer	Device results UCS MG4
Average strength values of basement walls	61 MPa	55 MPa	70 MPa
Average strength values of exterior silicate brick walls	8,1 MPa	7,8 MPa	8,8 MPa

According to the results, the device UCS MG4 shows more than the sclerometer by 27% and IPS MG4 by 15%. The result of the IPS MG4 device is greater than the sclerometer by 11%.

5. Conclusions

There were comparative analyses of the results of IPS MG4, sclerometer and UKS MG4 devices to determine the strength of reinforced concrete structures. As a result, the average results of the device UCS MG4 shows deviations up to ±25% than the devices IPS MG4 and sclerometer. The average results of the device IPS MG4 showed 10% more than the instrument sclerometer.

Control of reinforcement of reinforced concrete structures by electromagnetic method with IPA-MG4 and Elcometer 331 devices. As a result, the IPA-MG4 device showed on average 10% less than the Elcometer 331 device.

Comparative analysis of the results of the devices for determining the thickness of metal structures A1208 and UTM-MG4. The device A1208 showed an average error of 0.5%, and the device UTM MG4 showed an average error of 0.25%.

Comparative analysis of the results of the instruments for determining the humidity of building materials MG4D and Testo 606. These devices were used at the facility number 6 and as a result of the analysis the device MG4D showed more than Testo 606 on 13-22%, as MG4D measures the moisture surface of structures, and the device Testo 606 with a penetrating method. These places dampness can be fixed by thermal imaging, which gives temperature differences in the structures.

The advantage of the ultrasonic flaw detector A1220 MONOLITH when assessing the technical condition of concrete and reinforced concrete structures is to find voids, looseness in the body of the construction.

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