Formal Expert Examination of Materials and Structures in Order to Assess the Possibility of Their Re-use

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Abstract. The re-use of materials, structures and their elements in the construction of buildings and structures of various responsibilities is dictated by the need to reduce the cost of the final product. Quite often, the end consumer (that is the owner) does not even realise that re-used materials were applied for the construction of the object. The global task in this case is the established possibility of such application through a safety perspective. This requires the examination of materials and structures in order to assess the possibility of their re-use. In this study, the authors develop a methodical approach to such examinations, based on the existing normative-technical regulations. They also take into account their experience in inspection of materials and structures of re-used pipe piles in building construction.

Key Words: decision, quality, control, methodology, normative-technical, inspection, re-use, pipe pile, formal expert examination

1. Introduction
Being material-intensive, the building construction industry is the main consumer of reusable structures. Market competition in the construction industry often leads to the use of cheap building materials in the construction of buildings and structures. One way to reduce the cost of building materials is their re-use. This situation most frequently occurs when rolled metal products are involved, that is metal pipes. Pipes of repeated application are often used at production of welded pipe piles (WPP) as the main production material [1, 2].

2. Problem specification
Sheet pile wall is a load-bearing structure in the form of a vertical or inclined wall, erected (recruited) from such mounting elements as sheet piles with their lower parts driven into the earth and interconnected by longitudinal locks. According to GOST (All Union State Standard) R 52664-2010 "Welded pipe pile. Specifications", it is possible here to apply pipes of repeated application

Structurally, a pipe pile consists of a pipe and a pair of mating connectors (locks) welded to it. Usually, the scheme looks like that: pipe – lock – pipe. Tubular sheet wall, in its turn, is an engineering structure which is made of several tubular sheets sequentially driven into the earth and connected by their own locking elements or connectors. Tubular welded pile serves as a waterproof barrier and keeps the soil from collapsing during the construction of hydraulic structures (dams, embankments, lock chambers, docks, bridges, etc.) both as a temporary and permanent fence of pits and trenches.

WPP profiles are made of steel electric welded straight-seam pipes according to GOST 10704, GOST 10705, GOST 10706 or of weldless hot-rolled pipes according to GOST 8732. Two locks are fixed to these pipes with welded joints which are located in the diametrical plane in accordance with Figure 1.
According to consumers requirements, manufacturing facilities also produce WPP angular profiles with locks arranged in two radial planes under a certain required angle (as shown in Figure 2).

The main WPP element, that is hot-rolled or welded straight-seam pipes, should be made of structural low-alloy steel; Grades 09G2S, 17G1S (17G1SU), 09GSF, Strength class K52 (C-345); and Grade 10G2FBU, Strength class K60 (C-540) as according to GOST 19281 [3].

In general, the confirmation of the steel grade is carried out on the basis of the following:

- the chemical composition of steel by ladle sample analysis (new materials);
- values of mechanical properties during tensile testing (yield strength, time resistance, elongation);
- fracture toughness;
- ultrasonic inspection of sheet and (or) weld integrity;
- with a guarantee of weldability (HS) with a normalized carbon equivalent.

3. Normative regulation on the use of pipes that were previously in use

As of May 2019, there is a significant number of pipes that were previously used which are in need of assessment of the possibility of their re-use. We further provide a list of construction rules limiting the use of used pipes:

1. SP 16.13330.2011 "SNiP (Construction Rules and Regulations) II-23-81* Steel structures”.
2. SP 22.13330.2011 "SNiP 2.02.01-83* Foundations of buildings and structures”.
3. SP 24.13330.2011 "SNiP 2.02.03-85 Pile foundations”.
4. SP 25.13330.2011 "SNiP 2.02.04-88 Bases and foundations on permanently frozen soils”.
5. SP 31.13330.2012 "SNiP 2.04.02-84* Water supply. External networks and facilities”.
6. SP 32.13330.2012 "SNiP 2.04.03-85 Sewerage. External networks and facilities”.
7. SP 35.13330.2011 "SNiP 2.05.03-84* Bridges and pipes”.
8. SP 58.13330.2012 "SNiP 33-01-2003 Hydraulic structures. General requirements".
9. SP 62.13330.2011 "SNiP 42-01-2012 Gas-distribution systems".
10. SP 70.13330.2012 "SNiP 3.03.01-87 Bearing structures and building envelopes".
11. SP "Marine berthing facilities. Rules of design and construction" (new specifications).
12. SP 100.13330.2011 "SNiP 2.06.03-85 Reclamation systems and structures".
13. SP 277.1325800.2016 "Marine bank protection structures. Design rules".

The use of materials and structures of tubular welded sheet piles allows the application of pipes that were previously in use in order to establish the possibility of their re-use. Therefore, the use of examination methods to assess the quality of materials in the structures of tubular welded sheet piles in order to establish the possibility of their re-use is relevant and significant due to the frequent use of these parts (materials) as main elements, both in temporary and permanent structures.

4. Formal expert examination of WPP materials and structures in order to assess the possibility of their re-use

The authors further describe the sequence of procedures for the examination of materials and structures of tubular welded sheet piles in order to establish the possibility of their re-use at all stages.

4.1. Examination of materials – WPP elements – on the manufacturer facilities

The quality of steel rolled products supplied to the manufacturer must be certified by certificates or passports of the enterprise-suppliers. The use of rolled stock without certificates (passports) is not allowed. If such certificates do not contain all necessary data, the manufacturer of the sheet pile profiles should perform all required laboratory tests in accordance with the requirements established in the regulations [6-8].

If the test results meet the requirements of regulatory documents, the materials can be used for the manufacture of structures. Moreover, these test certificates are attached to the existing certificates. The maximum permissible values of surface defects of previously used pipes should not exceed values specified in Table 1.

Table 1. Maximum permissible values of surface defects of previously used pipes

| Type of defect                              | Threshold limit values |
|--------------------------------------------|------------------------|
| Surface area occupied                      | The average remaining |
| Uniform steel corrosion                     | wall thickness $t_{rem}$ |
| 100%                                       | 0.95 t                 |
| Local defect (ulcer corrosion, ripple       | 0.50%                  |
| markings, risks, conditioning floors, etc.)| 0.93 t                 |

$t_{rem}$ is the nominal wall thickness of the pipe; $t_{ost}$ is the average residual wall thickness of the pipe, determined in accordance with 7.1.1 GOST R 52664-2010 Welded pipe pile. Technical requirements.

It is possible to use the pipe and rolled stock for locks with welded connections of units, that is with transverse joints. The number of transverse joints in the pipe sheet pile should not exceed the following values:

- one – with a profile length of less than 12 m;
- two – with a profile length from 12 to 24 m.

The minimum distance from the end of the pipe to the nearest joint is 1 m. The distance between the joints of the pipe must be at least 3 m.

4.2. Examination of WPP constructions at the manufacturing facilities

Welded joints should be performed by automatic or semi-automatic submerged-arc welding and in a shielding gas environment. Manual electric arc welding is also allowed. The types and technology of welding used in WPP manufacture shroud provide a temporary resistance of the metal of welded joints not
lower than its standard value for the base metal and the value of toughness and elongation depending on the climatic zone.

Mechanical properties of welded joints should meet the requirements of GOST 23118. Welded joints of WPP profiles in the places of their connections of pipes with locks should be longwise continuous. Welded joints of sheet pile profiles should have continuous weld penetration to provide equal strength with the main section of the metal. The quality of welding materials should be certified by certificates of the enterprise-suppliers. Welding materials for automatic, semi-automatic and manual welding in the manufacture of sheet pile profiles should be used with account of the strength class of steel, type of weld, welding method and design (conventional or northern). Limit deviations of the size of legs of welded angular joints from nominal value shall correspond to data given in Table 2.

Table 2. Limit deviations of the size of legs of welded angular joints from nominal value

| The nominal size of the leg of T-shaped, angular and lap-welded joints, mm | Limit deviations of legs, mm, according to welding method |
|---|---|---|
| | Automatic and semi-automatic submerged-arc welding | Automatic and semi-automatic in shielding gases | Manual welding with covered electrodes |
| Up to 5. | 1 | +1; -0.5 | +1; -0.5 |
| St. 5 to 8 included. | 2 | +2; -1 | +2; -1 |
| St. 8 to 12 included. | 2.5 | +2,5; -1,5 | +2,5; -1,5 |
| Available angular weld incurvation | Up to 30% of the value of the leg, but not more than 3 mm |
| Available angular weld convexity | Up to 15% of the value of the leg, but not more than 3 mm |

According to consumers requirements, a protective paint coating is applied to the sheet pile profiles, the characteristics and technology of which are determined by the consumer in agreement with the manufacturer. This characteristic should be given in the passport for the ready-made product – WPP.

5. Results and discussions, conclusions

During the examination of the construction of the object "Combined berth for large-capacity equipment for the event "Hydrocracking complex. Large-capacity equipment (LCE) route" there was the examination of materials and structures in order to assess the possibility of their re-use. Figure 3 shows a general view of the structures under analysis.
On the basis of the expertise provided in the executive and project documentation for the object "Combined berth for large-capacity equipment for the event "Hydrocracking complex. LCE route" [9] it is possible to draw the following conclusions:

1. According to consumers requirements, a protective paint coating was applied to the following sheet pile profiles: to tubular metal piles: lacquer BT-577 was applied for the entire length; to tubular welded pipe piles (LPP): two-component chemical resistant material "PRIM PLATINUM", 150 microns thick, was applied. Data on the quality of painting are not available.

2. According to p.6.3 of GOST R 52664-2010, incoming inspection of pipes that were previously in use should be carried out on a batch of pipes of the same diameter and wall thickness formed from pipes that were previously used on one object. The number of pipes in the lot shall be not more than 100 pieces. On the basis of the enclosed documents (repeated in each passport for piles tubular metal Ø820*10(9), and the welded pipe piles (WPP)) which include the letter from JSC TsNIIS No. 532910/21, dated 03.08.2011, and Protocol Metaltest No. 705/4-2010, dated 23.07.2010, it can be concluded that incoming inspection of re-used pipes was not properly conducted, because only one sample of Pipe 820*10 was tested.

3. According to p. 5.17.3 of GOST R 52664-2010, the statement of results of welded joints quality control was not provided.

4. According to p. 6.3.2 GOST R 52664-2010, the residual thickness of the metal is determined by the results of random samples inspection. The required sample size should be 10% of the number of pipes in the batch, but not less than five pieces. No measurement data available.

5. According to p. 6.3.4 GOST R 52664-2010, mechanical properties of the base metal and the weld joint is determined by the random samples inspection. The required sample size should be at least two tubes per batch. No measurement data available.

6. According to p. 6.6 of GOST R 52664-2010 GOST 14782, or to radiographic control according to GOST 7512, the amount of inspected welded joints shloud be 100%. No measurement data available.

7. According to p. 7.1 of GOST R 52664-2010 there supposed to be incoming inspection of pipes that were previously used. No input control data is provided.

The authors further provide the conclusions on the visual inspection and instrumental examination of materials and structures used for the object "Combined berth for large-capacity equipment for the event "Hydrocracking complex. LCE route":

1. The actually used material, that is previously used pipes from the dismantled pipeline site, re-used pipes (with quality certification) meet the requirements of GOST 10704-91 "Electrically longitudinal welded steel pipes. Range of sizes", GOST 10704-76 "Electrically longitudinal welded steel pipes. Range of sizes", GOST 10704-67 "Electrically longitudinal welded steel pipes. Technical requirements" for St3sp, data of the certificate of quality for durability group K 52 according to GOST 202-95 "Welded steel pipes for mainstream gas and oil pipelines"), GOST 19281-89 "Rolled stock from the increased durability steel. General specifications" for strength class C345 [10-14].

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3. Ultrasonic inspection of 4 piles of visible (surface part) according to GOST 14782 revealed 12 defects.

4. The nominal size of the angle joint leg does not meet the requirements of GOST R 52664-2010.

5. There is no inspection stamp of the manufacturer.

Thus, it is possible to make a general negative conclusion on the examination of materials and structures in order to establish the possibility of their re-use for the object "Combined berth for large-capacity
equipment for the event “Hydrocracking complex. LCE route”. To prevent such situations, it is proposed to conduct a modular inspection of acceptance control [15-16]. The acceptance control test criteria are shown in Figure 4.

![Figure 4. Acceptance control test criteria](image)

In case of unsatisfactory results of the assessment it is necessary to send a claim to the contractor, in case the complaint rejection within 10 days it is recommended to go to court in accordance with the requirements of the Russian legislation.

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