Testing of load-carrying elements of elevating equipment while reconstruction transport facilities

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Abstract. The authors of this paper briefly overview the history of the world’s elevator industry and provide the main existing elevator classifications by technical and other features. In order to avoid any possible discrepancies the fundamental differences between Elevator” (Elevating equipment) and “Hoist” are shown. Regulatory requirements for mandatory design of lifting mechanisms at various facilities are considered. The paper also describes tests of elevator equipment elements (in particular, mounting loops in elevator shafts) that need to be conducted at the stage of commissioning a facility to ensure further safe operation of an elevator, as well as a safe replacement of elevating equipment in the process of repair and preventive maintenance. The list of executive documentation required for commissioning of lifting equipment is presented. Schemes of tested elevator’s loop with a detailed description of some necessary elements are given. The main stages of tested elevator’s loop with the use of photos are considered. Due to the lack of regulatory documentation it is necessary to conduct full-scale tests that are based on the strength of materials calculations and reliability of structural elements. Analytical representation example of full-scale tests of elevator’s explosive loops installation is also exhibited. The study examined the objects of transport infrastructure.

1. Introduction
Lifting mechanisms first started to serve the production needs of a human as early as the time of the Roman Empire ([1, 2], for details see also Figure 1). However, a considerable leap forward in the improvement of the world elevator manufacturing industry (elevators as a type of a hoist machine) was made amidst explosive development of capitalism in Europe and North America in the 19th – early 20th centuries alongside rapidly growing manufacturing industry (metallurgy, machine engineering etc.) ([3, 4], see Table 1).

Table 1. Specifications of first elevators - prototypes of modern elevating equipment.

| No. | Designed in, year | Country | Brief description |
|-----|-------------------|---------|------------------|
| 1.  | 1850              | USA     | Waterman elevator |
| 2.  | 1852              | USA     | Otis elevator with elevator cab safety system being activated when the cable breaks |
| 3.  | 1880              | Germany | First DC-driven elevator by Siemens with a gearing system to climb wall shafts fitted with racks |
2. Material and methods

Today, there is a great variety of lifting equipment classified by different features see Tables 2 and 3 [5, 6]. Current regulations governing design practices call for the installation of elevating equipment in buildings having 3 floors or taller or being 9.9 meters high or taller; for details see Table 4. Virtually this means that in a modern rapidly growing city, lifting mechanisms are present in almost every more or less considerable capital construction, restoration or repurposing project.

Table 2. Classification of elevating equipment by main features.

| No. | Type of classification | Types of elevating equipment |
|-----|------------------------|------------------------------|
| 1.  | Designation            | Passenger (normally having load capacity from 350 to 500 kg) |
|     |                        | Freight and passenger (load capacity from 500 kg) |
|     |                        | Hospital |
|     |                        | Freight |
|     |                        | Special (e.g. an elevator to lift firefighting crews) |
|     |                        | Carrier decks |
|     |                        | Industrial |
|     |                        | Elevator for people with impaired mobility (the disabled) |
| 2.  | Type of hoist drive    | Electric |
|     |                        | Hydraulic |
| 3.  | Type of mechanism transmitting motion to a car | Rope |
|     |                        | Chain (rack and screw) |
| 4.  | Type of motion transmission | Drum hoist |
|     |                        | Traction sheave |
| 5.  | Type of cable connection | With on top cable connection |
|     |                        | Hydraulic elevators (underslung) |
| 6.  | Receiving scheme       | Direct |
|     |                        | Polyspast |
|     |                        | With cable multiplier |
| 7.  | Machine room location  | Top |
|     |                        | Bottom |
|     |                        | Without machine room |
8. **Winch drive design**
   - Geared
   - Gearless

9. **Cab travel speed**
   - Low speed \( (v \leq \frac{1}{c}) \)
   - Fast rise \( (\frac{1}{c} < v \leq \frac{2}{c}) \)
   - High speed \( (v > \frac{2}{c}) \)

10. **Elevator cab leveling**
    - With leveling system
    - Without leveling system

11. **Gearing diagram of an elevator**

12. **Design specifics**
    - Internal
    - Frontal
    - Panoramic

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**Table 3.** In everyday use, terms “Elevator” and “Hoist” are often confused. Fundamental distinctions between “Elevator” (Elevating equipment) and “Hoist”.

| No. | “Elevator” (Elevating equipment) | “Hoist” |
|-----|----------------------------------|--------|
| 1.  | Control unit is always inside a cab | Control unit may be located outside |
| 2.  | Mandatory registration with Federal Service for Environmental, Technological and Nuclear Oversight of Russia (Rostechnadzor) | Registration with Rostechnadzor is not necessary |
| 3.  | Highest load \( \gg 800 \) kg | Highest load - up to 800 kg |
| 4.  | - | Simplified construction of a mechanism providing attachment to load-carrying structures |

**Table 4.** Regulatory requirements to mandatory design of lifting mechanisms at different facilities.

| No. | Facility designation | Regulatory control | Margin parameters allowing elevating equipment not to be installed at facility |
|-----|----------------------|--------------------|--------------------------------------------------------------------------------|
| 1.  | Residential buildings | Construction rules SP 54.13330.2011 “Multicompartiment residential buildings”. Revised edition of Construction Rules and Regulations (SNIp) 31-01-2003”, article 4.8 | Facilities up to 12.0 meters high |
| 2.  | Public buildings | SP 118.13330.2012 “Public buildings” | Facilities up to 9.9 meters high |
3. Results and discussion
Prior to commencement of elevating equipment installation (which is generally provided by a dedicated installation contractor) inside a shaft (with completed shaft openings) bearing capacity [7] and stress-strain performance [8] of installation loops of elevating equipment (see Figures 2 and 3) shall be tested (see Table 5). These loops are designed to carry loads at the initial stage of a cab installation and in the course of preventive maintenance, when elevator tracks shall be unloaded by transferring the load from an elevator cab to the mentioned installation loops anchored in the structures of a solid-cast concrete shaft (stiffening core) (for more details of the testing procedure – see Tables 6, 7, 8 and Figure 4). These tests have been made mandatory to comply with existing Technical safety guidelines [9, 10] following cancellation of regulations that had been in effect earlier. However, notwithstanding the importance of these control procedures, yet there are no regulatory documents with explicit requirements to procedures of in-situ testing of installation loops of elevating equipment. In real terms, it all comes down to the development of process regulations or a testing program for a construction testing laboratory for each project individually followed by obtaining approvals of other involved project offices (Customer, Operations, Developer - EPC contractor, Dedicated elevator installation provider, in some specific cases - representatives of a government's compliance control office etc.)

Table 5. List of as-built documentation necessary for the commissioning of elevating equipment.

| No. | Title of as-built documentation necessary for the commissioning of elevating equipment |
|-----|------------------------------------------------------------------------------------|
| 1.  | CERTIFICATE of readiness of a construction part for elevating equipment installation works |
| 2.  | REPORT on equipment faults detected in the course of inspection, installation and testing |
| 3.  | CERTIFICATE of acceptance of equipment for installation |
| 4.  | CERTIFICATE of readiness of scaffold in a shaft and fencing of shaft openings for elevating equipment installation |
| 5.  | CERTIFICATE of readiness of an elevator for finishing operations |
| 6.  | CERTIFICATE of readiness of an elevator for commissioning |
| 7.  | CERTIFICATE of commissioning of a system (package) |
| 8.  | CERTIFICATE of testing a component of a system (package) |
| 9.  | CERTIFICATE of a component testing of a system (package) |
| 10. | As-built drawing of an elevator concrete shaft |
| 11. | As-built drawing of an elevator brick shaft |
| 12. | Reports on installation loops testing |
Figure 2. Drawing of a lifting loop made of reinforcement steel.

Figure 3. Test configuration.

Where: 1 – elevator shaft coating; 2 – lifting loop being tested; 3 – dial gauge with a supporting arm to keep track of residual deformation of lifting loops; 4 – steel hoist cable; 5 – system of manual chainfalls with pulley blocks; 6 – dismantled board of timber flooring to make way for a steel cable; 7 – fixed cable (top load is 3.5 t) to create a carrying element; 8 – work platform from timber strips (designed conventionally); 9 – steel supporting elements of a work platform (I-beams No.16B), embedded in solid-cast concrete structures of an elevator shaft, also being a part of a carrying element; 10 – weight measuring equipment to record imposed load, kilogram-force; 11 – bracings in the bottom flanges of bearing beams to ensure stability from the beam plane.

Works were implemented from erection decks built as per design and envisaging that the highest load from workers and testing equipment would be 1200 kg or less. In the course of testing, no more than 2 lab technicians can stay on a base platform floor at the same time.
Table 6. Phases of testing of elevator installation loops.

| No. | Phase of testing of elevator installation loops | Taking photos of testing of elevator installation loops |
|-----|-------------------------------------------------|--------------------------------------------------------|
| 1.  | Development of a testing program or process regulations | Not available                                           |
| 2.  | Reconnaissance survey by a test team of a construction laboratory. General view of installation loops in an elevator shaft at construction site | |
| 3.  | Placement of auxiliary means and additional pavement to ensure stable positioning and safety of testing personnel and equipment in an elevator shaft under construction | |

![Image of elevator installation loops](image-url)
4. Installation of a displacement sensor (dial type) on an installation loop in a shaft

5. Fixing of a chainfall on an installation loop in a shaft

6. Taking dial-type displacement sensor readings at a preset load

7. Processing results in the office and providing conclusions and recommendations
| No. | List of applicable equipment | Note | Image |
|-----|------------------------------|------|-------|
| 1.  | Loading equipment            | E.g., chainfall | ![Image](loading_equipment.png) |
| 2.  | Displacement sensor          | E.g., dial gauge | ![Image](displacement_sensor.png) |
| 3.  | Auxiliary pavement means     | As a limiting and supporting structure | ![Image](auxiliary_pavement.png) |
| 4.  | Force-measuring equipment    | E.g., Crane scales | ![Image](force_measuring_equipment.png) |
| 5.  | Set of clevises              | Of different diameters | ![Image](set_of_clevises.png) |
### Table 8. Sample analytical representation of in-situ pull-out testing of elevator installation loops.

| Number of an elevator shaft | Number of an installation loop | Load degree | Displacement, mm | Load, ton-force |
|----------------------------|-------------------------------|-------------|------------------|-----------------|
| 1                          | 1                             | 0.00        | 0.20             |
| 2                          | 1                             | 0.19        | 0.40             |
| 3                          | 1                             | 0.29        | 0.60             |
| 4                          | 1                             | 0.59        | 0.80             |
| 5                          | 1                             | 0.89        | 1.00             |
| 6                          | 1                             | 0.99        | 1.20             |
| 7                          | 1                             | 1.19        | 1.40             |
| 8                          | 1                             | 1.39        | 1.60             |
| 9                          | 1                             | 1.69        | 1.80             |
| 10                         | 1                             | 1.89        | 1.90             |

### Figure 4. Test configuration.

4. Conclusion

Installation loops of elevating equipment are one of the major parts of elevators design. They get connected to components, which fix elevator cabs in shafts. Both GOST and SP do not contain specific conditions for testing elevator loops. Therefore, a need for testing shall be based on calculations of material strength, reliability of structural elements [11, 12]. This information is set forth in the Terms of Reference and design documentation.

In-situ pull-out testing of elevator installation loops carried out in a relevant manner allows for stress-related behavior and bearing capacity of such elements to be determined with a reasonable degree of accuracy. These tests allow for reliable and safe elevator assembly and installation work at the stage of transport facility construction, commissioning of facility as well as in the course of operations (routine and preventive maintenance).

### References

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