Improving Protective Equipment in the High-Rise Construction

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Abstract. The article considers the problem of organizing the workplace in the high-rise construction. If the workplace has a mark above 1.3 m from any base or closer than 2 m horizontally to the vertical drop, then it qualifies as a workplace at altitude. Climbing work begins at 5.0 m. It is estimated that approximately 50% of all accidents during installation work due to the fall of people from above. This is usually caused by deficiencies in the arrangement of the workplace. The analysis of existing and new types of devices for safe installation in the high-rise construction and the reasons of injury when working with building cranes are also investigated.

1. Introduction
Safety standards and rules that apply to construction and special construction works, including in the high-rise construction, regardless of the departmental subordination of organizations performing these works, are contained in the regulatory building Codes, construction Safety Standards, which particularly exposed to high-risk factors to minimalizing cases of injuries and fatalities of workers in the construction sites and improving the workplace: EN1263, the European standard for safety netting, ISO 10137:2007, ANSI/ASA S2.71-1983, SN 2.2.4/2.1.8.566-96 (in Russian) - standards for vibration protection in the high-rise building construction, etc. [1-5].

In order to improve working conditions, it is advisable:
- conduct a special assessment of working conditions;
- apply preventive measures aimed at reducing
  - occupational injuries and occupational diseases;
- conduct continuous training of employees on occupational health based
  - modern teaching technologies;
- improve the regulatory framework;
- organize information support during the construction process.

When choosing safety fans with a protective mesh, which usually have two standard lengths of 4.2 meters or 6 meters, you need to make sure that they have passed the tests for compliance with EN1263 [5] and have proved that they are able to stop falling to 100 kg from a height of 6 meters. The protective mesh fan should also include a 60 x 60 mm lockable mesh and an additional thin 20 x 20 mm alloy mesh together to provide protection from everything from large objects, such as lowered tools (Figure 1).
2. Methodology

2.1. Factors affecting the working conditions of the construction process
The article uses the method of scientific forecasting of labour safety. A systematic approach to solving the problem of labour safety involves the study of the full totality of factors affecting working conditions, on all stages of the construction process. The areas of permanent hazardous production factors relate to:

- places near uninsulated live parts;
- electrical installations;
- places close to unshielded swings at a height of 1.3 m or more;
- places where exceeding the maximum permissible concentrations is possible;
- harmful substances in the air of the working area.

The areas of potentially hazardous production factors should be related to:

- sections of the territory near the building (structure) under construction;
- floors (tiers) of buildings and structures in one capture over which mounting (dismantling) of structures or equipment;
- areas of movement of machinery, equipment or their parts, workers organs;
- places over which the movement of goods by cranes.

2.2. Protecting the workforce and anti-vibration protection of workers at the height of the construction site
The vibration occurs during the operation of machines and mechanisms having unbalanced and unbalanced rotating organs or organs with reciprocating and shock movements. Such equipment
includes metalworking machines, forging and stamping hammers, electric and pneumatic perforators, power tools, as well as drives, fans, pump units, reciprocating and centrifugal compressors, grinders, vibrators, etc. Vibration is used for compaction of concrete mixtures, crushing and sorting of inert materials, unloading and transportation of bulk materials, loosening frozen ground, piling, etc.

Vibration refers to factors with high biological activity. The severity of responses is mainly determined by the strength of the energy effect and the biomechanical properties of the human body as a complex oscillatory system. The power of the oscillatory process in the contact zone and the time of this contact are the main parameters that determine the development of vibrational pathologies, the structure of which depends on the frequency and amplitude of the vibrations, the duration of exposure, the place of application and the direction of the axis of the vibrational effect, the damping properties of tissues, resonance phenomena and other conditions.

The systematic effect of general vibrations with a high level of vibration velocity leads to a vibrational disease, which is characterized by disturbances in the physiological functions of the body associated with damage to the central nervous system. These disorders cause headaches, dizziness, sleep disturbances, decreased performance, poor health, cardiac disturbances, visual disturbances, numbness and swelling of the fingers, joint disease, and decreased sensitivity.

At the height of the construction site, vibrations from the underlying platform often occur, where workers are more often exposed to environmental vibrations, therefore they are more likely to suffer from cardiovascular and nervous diseases and usually present many somatic complaints.

The human body is considered as a combination of masses with elastic elements having their own frequencies, which for the shoulder girdle, hips and head relative to the supporting surface (standing position) are 4 ... 6 Hz; head relative to the shoulders (sitting position) - 25 ... 30 Hz. For most internal organs of natural frequency lie in the range of 6 ... 9 Hz (Figure 2).

![Figure 2. The model of frequency and direction of the human vibrations](image)

To eliminate the harmful effects of vibration on workers, modern protection methods should be applied:
- reduction of vibration in the source of its formation by structural or technological measures;
- reduction of vibration along its path by means of vibration isolation and vibration absorption;
- remote control, eliminating the transmission of vibration to the workplace;
• personal protective equipment (mittens and gloves with anti-vibration pads, shoes with anti-vibration insole made of plastic or rubber).

3. Results and discussions
Vibration isolation is achieved by installing aggregates on special elastic devices (supports) with low rigidity. Often during the operation of machinery and equipment unacceptably strong vibrations of reinforced concrete floors are excited, on which the operator’s workplace is located. These vibrations adversely affect the health of the operator. The main way to protect workplaces in such cases is the use of passive vibration isolation, when spring vibration isolators are installed between the operator’s platform and the base.

Calculation of passive vibration isolation is carried out in the following sequence.
1. Determine the vibrational velocity (vibration velocity) of the overlap by the formula:

$$v = \frac{2 \pi f A_z}{\text{cm/s}}$$

(1)

where $f$ is the frequency of forced vibrations of the base, Hz;
$A_z$ is the actual amplitude of the base vibrations.

2. Determine the required coefficient of vibration isolation according to the formula:

$$C_i = \frac{v_0}{v} < 1,$$

where $v_0$ is the maximum permissible value of vibration velocity in accordance with sanitary standards SN 2.2.4 / 2.1.8.566-96 “Industrial vibration, vibration in the premises of residential and public buildings” [6]. This factor must be much less than unity in order to meet the requirements of sanitary standards for limiting vibration. In practical calculations, they are often set by the transfer coefficient: $C_i = 1/40 \ldots 1/60$.

3. To determine the frequency of free (intrinsic) vertical vibrations of the site according to the formula:

$$f_0 = \frac{f}{\sqrt{C_i} + 1}, \text{Hz}.$$  

(2)

4. Knowing the weight of the platform $Q_1$, kg and the weight of the operator $Q_2$, kg, calculate the total weight equal to $Q = Q_1 + Q_2$ (kg).

It should be borne in mind that for sites installed on an oscillating base (workshop floor, floor, etc.), the weight of the slab should exceed at least 2-3 times the weight of workers who may be on the site.

Determine the total stiffness of the springs of this site by the formula:

$$C_z = \frac{Q \cdot f_0^2}{25}, \text{kg/cg}$$

(3)

5. Determine the static settlement of all springs by the formula:

$$X_{st} = \frac{Q}{C_z}, \text{cm}.$$  

(4)

6. Determine the stiffness of one shock absorber:

$$C'_z = \frac{C_z}{n}, \text{kg/cg}$$

(5)

where $n$ is the number of shock absorbers (springs).
7. Determine the calculated load per spring by the formula:

\[ P' = P_{at} + 1.5P_{dim} = \frac{Q}{n} + 1.5 \frac{Q}{n^1}, \text{kg}, \]

(6)

where \( n^1 = 2 \), it is accepted from the conditions that the weight of the operator is distributed on two springs.

8. Determine the diameter of the spring bar by the formula:

\[ d = 1.6 \sqrt{\frac{kPC}{[\tau]}}, \text{cm}, \]

(7)

where: \( C = D / d \) - spring index - the ratio of the average spring diameter \( D \) to the diameter of the rod \( d \). It is recommended to take a value within 4 ... 10;
\( k = 1.18 \) - the coefficient is determined depending on the index of the spring \( C \);
\([\tau]\) - permissible torsional stress (shear, shear) for the spring material. For steel \([\tau] = 4500 \text{ kg/cm}^2\).

Round the design diameter \( d \) of the spring bar to the diameter \( d_1 \) adopted in GOST 9389-75 "Steel carbon spring wire. Technical conditions" [7].

9. Check the condition for ensuring the permissible shear stress in the spring material according to the formula:

\[ \frac{2.56kP'C}{d_1^2} \leq [\tau], \]

(8)

10. Determine the number of working turns of the spring by the formula:

\[ i_1 = \frac{Gd_1}{8C'C^3}, \]

(9)

where \( G \) is the shear modulus for the spring material, for steel \( G = 8 \times 10^5 \text{ kg/cm}^2\).

11. Determine the total number of turns of the spring:

\[ i = i_1 + i_2, \]

(10)

where \( i_2 \) - the number of idle turns take:

\( i_2 = 1.5 \) turn on both ends for \( i_1 < 7 \);

\( i_2 = 2.5 \) turns for \( i_1 \geq 7 \).

12. Determine the pitch of the coil of the spring from the conditions:

\[ h = (0.25 \ldots 0.50) \cdot D, \text{cm}, \]

(11)

where \( D = C \cdot d_1 \), cm.

13. Determine the height of the unloaded spring:

\[ H_0 = i_1 \cdot h + (i_2 - 0.5) \cdot d_1, \text{cm}. \]

When calculating compression springs, to fulfill the stability condition, it is necessary that the ratio of the height of the unloaded spring to its average diameter be no more than 1.5. As a result of the calculation should be:

\[ \frac{H_0}{D} \leq 1.5. \]

(12)

The draft of the vibration isolator, on which a passively vibration-insulated plate is installed, when moving along the plate of one person, whose weight is assumed to be equal to 80 kg, should not
exceed 10 mm. Practical observations from field measurements were also obtained by other scientists during their research, the main task of which was to provide a safe and ergonomic workplace [8-11]. In this case, we showed the calculation of passive vibration isolation for workers at the construction sites, located at the height of the platform.

4. Conclusions
Thus, the development of new equipment installed on the marketplace is for sale for installation directly on a permanent or concrete frame to a giant building or timber structure using a wide range of special personalities. Improving protective equipment in the high-rise construction allows ensuring safe high-quality performance of work throughout the entire life cycle of the facility. In the conditions of the high-rise building construction, unacceptably strong vibrations of the reinforced concrete slab, on which the workplace is located, are excited. These vibrations adversely affect the health of workers. The main way to protect workplaces in such cases is to use passive vibration isolation, when spring vibration isolators are installed between the work platform and the base.

The article considers the calculation of passive vibration isolation in a certain sequence and provides examples of modern protective equipment during construction work at heights.

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