MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
FACULTY OF ARCHITECRURE, CONSTRUCTION AND DESIGN
COMPUTER TECHNOLOGIES OF CONSTRUCTION DEPARTMENT

TO ADMIT TO GUARD
Head of the Department
____________O.I. Lapenko
"_____" _____________ 2020

# MASTER THESIS

## (EXPLANATORY NOTE)

**Topic:** Reconstruction of the production building in order to increase its technical and economic level
**Performed by:** Student of group 205ma, Al-Badri Ali
(student, group, last name, first name, patronymic)

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Kyiv 2020

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

НАВЧАЛЬНО-НАУКОВИЙ ІНСТИТУТ АЕРОПОРТІВ
КАФЕДРА КОМП'ЮТЕРНИХ ТЕХНОЛОГІЙ БУДІВНИЦТВА

ДОПУСТИТИ ДО ЗАХИСТУ

Завідувач випускової кафедри

____________О.І. Лапенко

"_____" _____________2020 р.

# ДИПЛОМНА РОБОТА

## (ПОЯСНЮВАЛЬНА ЗАПИСКА)

**ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА**

**ЗА СПЕЦІАЛІЗАЦІЄЮ «ПРОМИСЛОВЕ І ЦИВІЛЬНЕ БУДІВНИЦТВО»**

**Тема:** Реконструкція виробничого корпусу з метою підвищення його техніко-економічного рівня

**Виконавець:** студентка групи 205м Аль-Бадрі Алі
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Київ 2020

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет архітектури, будівництва та дизайну
Кафедра комп'ютерних технологій будівництва
Спеціальність: 192 «Будівництво та цивільна інженерія»
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ЗАТВЕРДЖУЮ
Завідувач кафедри
___________О.І.Лапенко
«____»__________2020 р.

**ЗАВДАННЯ**
**на виконання дипломної роботи**

Аль-Бадрі Алі
(П.І.Б. випускника)

1. Тема роботи Реконструкція виробничого корпусу з метою підвищення його техніко-економічного рівня

затверджена наказом ректора від «__» __________2020р. №             .

2. Термін виконання роботи: з 15 вересня 2020р.  по 15 листопада 2020р.

3. Вихідні дані роботи: Головна будівля, яка складається з:

Будівля залу складу, ремонтної майстерні та мийки пов'язана з адміністративною будівлею - мостовим краном, системою відводу відпрацьованих газів, системою трубопроводів стисненого повітря та одностороннім дахом; ця прибудова залу може бути продовжена з північно-західної сторони (вісь фронтону A-G / 12) ще двома полями залу, включаючи дахи.

Комбінована будівля, розділена на дві частини насосною будівлею під:

- обладнання для водопостачання питної води зі свердловин, які також повинні бути побудовані, - до власної системи водопостачання, включаючи належне йому обладнання водопідготовки, резервуари для зберігання води, опалення та, при необхідності, супутнє опалення трубопроводів; електричний живильний насос, трубопровідна система, фітинги, обладнання автоматичного регулювання та управління та пристрій наповнення водяних пожежних баків;

4. Зміст пояснювальної записки:

Реферат

4.1. Науково-аналітична частина……………………………………………...___
4.2.Архітектурний розділ…………………………………………………..___
4.3. Розрахунково-конструктивний розділ……………………………………___
4.4. Основи і фундаменти………………………………………………...___

4.5. Охорона праці……..………………………………………..…………..….___
4.6. Охорона навколишнього середовища ………………………………..….___

Список використаної літератури……………………………………………___

5. Перелік обов’язкового ілюстративного матеріалу: таблиці, рисунки, діаграми, графіки.

6. Календарний план-графік

| № з/п | Завдання | Термін виконання | Підпис керівника |
|---|---|---|---|
| 1. | Розробка архітектурного та розрахунково-конструктивного розділів | вересень 2020–листопад 2020 | |
| 2. | Проведення розрахунків основ і фундаментів, аналіз технічної експлуатації будівлі | жовтень 2020–листопад 2020 | |
| 3. | Опис та аналіз технології та організації будівництва | листопад 2020–грудень 2020 | |
| 4. | Виконання розділу «Охорона праці» та «Охорона навколишнього середовища» | листопад 2020–грудень 2020 | |
| 5. | Наукові дослідження | листопад 2020 | |

7. Консультація з окремих розділів:

| Назва розділу | Консультант (посада, П.І.Б.) | Дата, підпис | |
|---|---|---|---|
| | | Завдання видав | Завдання прийняв |
| Охорона праці | Доцент Коваленко В.В. | | |
| Охорона навколишнього середовища | Доцент Радомська М.М. | | |

8. Дата видачі завдання: «_15_» _вересня___ 2020 р.

Керівник дипломної роботи: ______________ Білокуров П.С

Завдання прийняв до виконання: ______________ Аль-Бадрі Алі

**CONTENT**

**Part 1**
**Introduction**

1.1. Analytical review ...........................................................................

**Part 2**

**Architectural part**

2.1. General architectural preview.....................................................................

**Part 3**

**Structural and design**

3.1. Characteristics of construction.......................................................................

3.2. Geological servey information.......................................................................

3.3. Design of metal structures for roof………………………………………………

**Part 4**

**Technical maintanance**

4.1. Technical Maintenance of building and structures…………………………….

**Part 5**

**Construction technology**

5.1. Dismantling of arched roof structures ……………………………………….

5.2. Dismantling of the old facades ………………………………………………

5.3. Installation of translucent enclosing structures…………………………………

5.4. Installation of facades from composite panels…………………………………..

5.5. Construction of a four-storey extension on axis in the axes B-I and a two-storey extension in the axes RT.........................................................................................

**Part 6**

**Organization of construction**

6.1. General decisions ……………………….................................................

6.2. General layout ………………………………………………………………..

**Part 7**

**Labor protection and safety equipment**

7.1. List of possible dangerous and harmful production factors............................
7.2. Basic organizational directions of creationof safe working conditions………
7.3. Types of harmful matters and their impact on human organism……………..
7.4. Sanitary-hygienic norms and control of harmful substances ………………..
7.5. Fire-fighting conditions and matters ……………………………………….

**Part 8**

**Environmental protection**

8.1. General Preview ………………………………………………………..
8.2. Energy saving and energy efficiency measures………………………………
8.3. Environmental protection measures ……………………………………….

**Part 9**

**Scientific-Research part**

9.1. Introduction……………………………………………...........................
9.2. Review of research on the properties and characteristics of epoxy materials..
9.3. Recommendations for strengthening the concrete beam of overlapping……
9.4. Design of strengthening using fiber materials………………………………..
9.5. Design of beam strengthening using advanced software. Lira SAPR………..

**Abstract**

1. **Analytical review**

Conversion of industrial areas, as well as reconstruction and technical re-equipment of individual industrial enterprises - a serious problem not only economic, but also architectural.

Industrial buildings, performing a structure-forming function, are actively influences the formation of the architectural appearance of cities. She has the emotional impact on the workers of factories and factories, on all citizens, brings additional variety to the architectural composition of streets and areas, due to its parameters and specific typological characteristics of architectural forms.

However, the modern physical condition of buildings and structures, architectural and aesthetic qualities of the part industrial facilities, the negative impact of obsolete equipment and technology for ecology leads to certain contradictions between production and city. It is often suggested to solve such problems liquidating even profitable production. At the same time, social and economic advantages of the location of industrial facilities in the structure of the city, including in direct connection with residential territories, the originality of the existing architectural environment is disturbed.

At the same time, by carrying out reconstruction measures, it is possible to achieve economic efficiency of production, solve environmental and transport problems, not only to restore the main production funds of enterprises, but also the original appearance of objects that have historical and cultural value, preserve architectural diversity urban space.

Achieving optimal results in the transformation of industrial objects is possible with a competent integrated approach to their reconstruction.

In this regard, the training of specialists is of particular relevance architects capable of solving a complex complex of reconstruction tasks industrial facilities as important components of the city structure with taking into account the specifics of the formation of the production environment and modern technological, constructive, social, environmental requirements.

Meeting future architects, regardless of the scope of their future activities, problems, methods and techniques of reconstruction ten industrial territories, complexes and buildings will prepare them for work with any complex multifunctional architectural objects.

An important task of modern architectural education is the formation of a worldview in which the industry is perceived as a necessary and organic part of any city, influencing it economy and quality of life of citizens, and therefore requires professional attention. Understanding of historical, architectural the values of the existing city environment and the role of industry in its integrity, along with knowledge of the specifics of the reconstruction of industrial facilities will allow students in their future professional activities competently resolve issues of urban space development, taking into account how interests of residents and production.

The main purpose of the proposed tutorial is to familiarize students with general reconstruction problems and assistance in mastering them basic methodological provisions for the reconstruction of industrial facilities, spread in domestic and foreign architectural practice.

Reconstruction in architecture - rebuilding the city, architectural complex, building, etc., caused by new living conditions.

Reconstruction objects in the field of industrial architecture can be: industrial zone of the city, including all industrial areas and individual enterprises; industrial area (node); industrial company; separate functional areas of an industrial enterprise (pre-factory, warehouse, engineering structures, etc.); industrial building; the interior of the production workshop. The named objects correspond different levels of spatial organization of industrial production.

In modern practice of reconstruction of industrial facilities a number of concepts are used that reflect either individual aspects of the process reconstruction, or specific approaches to carrying out reconstructive activities. These include:
Technical re-equipment - renewal and quality improvement characteristics of technological equipment.

Technical re-equipment includes a set of measures for increasing the technical and economic level of certain technological processes, replacement of physically worn out equipment of the main production and support services. In this case, often not only replacement of obsolete equipment, machine tools, machines and mechanisms, but also introduction of new promising technologies.

When carrying out activities of architectural and construction reconstruction industrial facilities are also expected to replace obsolete equipment and the introduction of new technology, but, as a rule, in a smaller volume and with the preservation of the existing technological process. Therefore the main difference between technical re-equipment and reconstruction is different proportion of the conversion of active and passive parts basic production assets.

With technical re-equipment, the development of production is usually assumed in the existing areas, without increasing the number of employees and without significant changes in the architectural parameters of industrial buildings.

Modernization of the technological process requires improvement its spatial organization and operating conditions, therefore technical re-equipment provides for a number of decisions regarding local architectural tasks. With technical re-equipment, it can reconstruction of the interiors of production workshops, correction of landscaping and landscaping, etc.

Renovation is the reconstruction of an architectural object in which based on the consideration of psychological, historical, aesthetic factors special zones of stability of the architectural space are created. This approach prevents negative perception of space by consumers its significant changes during the reconstruction of a separate industrial building, business or area. Conflict situations arise due to, noticeably manifested in recent years, the personal attitude of people to the architectural space in which they live and work.

Renovation as a reconstruction method is usually used whenchanging the functional purpose of the object, which often involves adjustment of the existing urban planning environment, therefore the concept of renovation is also used as a collective one, including adaptation and revitalization. allows solving the problem of continuity in the development of the urban environment.

Currently, the concept of renovation is in its infancy. Other processes are also determined by renovation in professional literature.

For example, renovation is an economic process of replacement or recovery of fixed assets retired from the process life activity as a result of physical and moral deterioration (in relation to urban planning products - the same as capital repairs). It seems that in relation to industrial facilities such the definition of renovation in a narrower sense duplicates the concept reconstruction and does not reflect the specifics of the renovation as a special complex reconstruction method.

Renovation of fixed assets in progress reconstruction seems to be the most economically feasible. When construction of a new enterprise the cost of construction and installation work accounts for 60% of all capital investments, with expansion - about 50%, during reconstruction - about 27%. Saving material resources when reconstruction of industrial buildings and structures allows for more efficient to use capital investments for the development of new equipment and technology, mastering the release of new types of products.

Another prevailing trend in architectural practice is design and construction of workshops with overestimation of their volumetric planning parameters with the expectation of the future development of technological process also proved to be ineffective. This is due to the fact that the pace and directions of technological progress are not always predictable, but operating costs of overestimated volumes and areas affect the cost of production of enterprises. Economically more expedient carry out phased reconstruction taking into account the requirements of the developing production.

A special aspect of the feasibility of the reconstruction of industrial objects as a way of developing production capacities is which creates the possibility of curbing the territorial growth of modern cities. This is important in the urban planning aspect, from an economic standpoint, on social and environmental requirements.

The need for the reconstruction of existing industrial facilities due to a number of reasons. With all the diversity and interconnection of them can be defined as socio-economic, technical and economic, urban planning, ecological, architectural and construction, aesthetic, social.

Social-economic reasons for the reconstruction of industrial objects are formed in the process of political and economic transformations taking place in the state and society.

The technical and economic reasons for the reconstruction are determining for industrial facilities and are associated with the need improvement of equipment and technology, with physical wear and tear and moral obsolescence of industrial equipment, buildings and structures.

Under physical or material wear and tear of an industrial building or its structural elements implies their gradual loss initial technical indicators. Preservation degree performance depends on the physical properties of the used building materials, on the type and geometric dimensions of structures, features of the location of the building on the ground, etc.

Obsolescence of an industrial building means the emergence of a discrepancy between its architectural and spatial parameters, performance, functional, technological sixteen appointment. With the acceleration of the development of science and technology, obsolescence of technological equipment is also accelerating.

# 2. Architectural part

## 2.1. Main architectural preview

The main building, which consists of:

- multi-storey administrative building-extension with an adjacent multi-storey technical building (extension) for the following premises: connecting room for connecting the building to external utilities; transformer; panel board, under the main switchboard with low voltage; compressor; boiler room; and electric generator (under the generator unit of emergency power supply);

Upon entering the building, the visitor has the opportunity to assess the interior and get in touch with staff. The reception desk has a large length. The head of service and the master of service are located nearby. Placing them in close proximity to the reception and the customer area provide an opportunity for good communication with the people involved in daily operations.

The hall building of the warehouse, repair shop and sink is connected to the administrative building - with a bridge crane, exhaust gas extraction system, compressed air piping system and one-sided roof; this hall extension can be extended from the north-west side (gable axis A-G /12) by two more hall fields, including roofs.

Combined building, divided into two parts pump building under:

- equipment for drinking water supply from wells, which must also be constructed, - to its own water supply system, including water treatment equipment belonging to it, water storage tanks, heating and, if necessary, accompanying heating of pipelines; electric feed pump, piping system, fittings, automatic regulation and control equipment and filling device of water fire tanks;

- diesel pump for fire water supply and appropriate piping system, fittings, equipment for automatic regulation and control, heating and, if necessary, accompanying heating of pipelines, etc.Sanitary and domestic services for employees in the production building (dressing rooms, showers, washrooms, toilets, etc.) are provided on the 2nd floor of the administrative and household annex. The wardrobe is divided into "clean" and "dirty" sections. Mechanics, coming to work, go into a clean section, where they leave the street and home clothes, and go to the "dirty" section, where they put on work clothes.

Various foundations, for example under the advertising pylon made by the customer (the sizes of a pylon, ShkhDhV: about 1,80 m x 0,50 m x 7,00 m); 7 flagpoles (flagpole height - 7.00 m), various mast mast supports, riser (subscriber) mailboxes, etc.

If required by law or regulations, a separate transformer building.

If necessary, a technical building for water clarification and / or separation (capture) installation.

If required by law or regulation, a separate emergency power generator building with appropriate control equipment.boxes, etc.

If required by law or regulations, a separate transformer building.The main load-bearing structures of the frame are transverse frames made of welded I-beams of variable cross-section. Frame pitch from 3.0 to 8.4 m.

The connection of the columns of the frames with the foundations is hinged. Connection of elements of a frame among themselves - rigid flange on high-strength bolts.

Vertical and horizontal connections are flexible, pre-tensioned from round steel.

At the ends of the building, the vertical and horizontal load is perceived by the load-bearing half-timber. Half-timbered racks are rigidly connected to the foundations.

Spatial rigidity and stability of the building is provided by joint work of cross frames, struts and vertical connections on columns and horizontal connections on a covering.

Runs of a roof are made of rolling channels on the inseparable scheme. Wall girders from Z-shaped profiles are made according to the split scheme.

In axes 1-4 and 4-6, A-H the overlapping on marks +3,800 and +3,900 accordingly for industrial premises is provided, and in axes 9-14, Ж-П - overlapping on a mark +3,300 under administrative and household premises.

Beams of overlappings are designed from rolled and welded I-beams.

Profiled flooring is placed on the floor beams, which performs the functions of a fixed formwork, on which a monolithic reinforced concrete slab is laid. Anchors are installed to connect the floor beams to the monolithic slab.

Fastening of a pro-thinned-out flooring to overlapping beams should be carried out in each groove by pyrotechnic nails with a diameter of 4,5 mm of the ENP 2-21L5MX brand of HILTI firm. Longitudinal connections of sheets of a corrugated board among themselves are carried out by the combined rivets with a diameter of 4,0 mm with a step no more than 500 mm.

In axes 5-9, f-g and 8-1, В-Ж load-lifting bridge cranes with a loading capacity of Q = 5,0t with a span of 26,0 m are provided, and in axes 8-14, A-C - the crane with a loading capacity of Q = 8, 0t span 18.0m.

All factory connections are welded, mounted on bolts of a class of accuracy "B" of a class of durability of 8,8 and high-strength bolts of a class of accuracy "B".

Belt seams in elements longer than 2.0 m should be performed by automatic submerged arc welding, other factory seams by semi-automatic welding in shielding gas. Welding materials for welding to accept from DBN "Steel designs".

At statement of bolts of normal accuracy it is necessary to provide measures against unscrewing of nuts by statement of spring washers or locknuts, the nuts of the high-strength bolts tightened to the set moment of tightening, are not fixed by anything in addition.

In connections on high-strength bolts axial tension of M24 bolts is accepted 24,4 ts, for M27 bolts - 31,8 ts. Tighten the bolts at the time of twisting. execution of connections on bolts to carry out according to "Methodical recommendations and specifications on technology of statement of bolts in assembly connections of a metalwork", M., 1988. To carry out a tension of high-strength bolts in the absence of backlashes in flange connections.

The load-bearing structure of the building can be made at the choice of the service provider of concrete, ready for laying, steel, masonry (limited to administrative premises and technical premises of the DE / 4-5 axis) or as a mixed structure. "masonry is undesirable.

Facing of the outer wall of the hall areas is performed with suspended, pre-manufactured industrial details of the facade. They can be made at the choice of the service provider or, depending on the fire protection regulations, as a cassette wall made of sheet steel or as a multilayer steel wall. The building belongs to IIIa degree of fire resistance.

Metal structures of the production building to cover with two layers of enamel PF15 GT 65-76 on one layer of primer GF-21 GT 2129-82 with a thickness of 30 microns.

Metal structures of administrative and household installation and stairwells are coated with a primer GF-021 GT 2129-82 thickness of 30 microns and fire-retardant coating, brand, thickness, composition and application technology which is developed and performed by a specialized organization that has certificates of conformity.

An element of concrete construction up to 1.00 m above the upper edge of the finished floor is made in the area of the plinth. This base can be combined with a frost-protective apron.

In the office area, a masonry façade or a concrete element façade with an external coated aluminum cassette façade shall be made, a minimum requirement of 3 mm with a metal cladding thickness of 0.5 mm, including region-specific insulation in accordance with local regulations and laws.

The roof of the hall area of the A-E / 5–12 axis is sealed with a mechanically fixed synthetic roof on the thermal insulation, and a trapezoidal sheet load-bearing wall cladding is laid. In the area of the office building of the A-E / 1–4 axis, the roof is sealed with a mechanically fixed synthetic roof on the thermal insulation, and a concrete floor is laid as a load-bearing element of the structure.

The passageway should be made as a facade of masonry or a facade of a concrete structure element with an external thermal insulation system and plaster with rough grout.

The roof is sealed with a mechanically fixed synthetic roof on the thermal insulation, and a concrete floor is laid as a load-bearing element of the structure. It should be noted that the protrusion of the roof is either thermally separated from the main roof completely (shock-insulating basket or similar), or is lined with insulation on all sides. Alternatively, the roof structure can be made of a wooden frame and wooden formwork on the upper side, with insulation and a mechanically fixed synthetic roof.

Water tanks for firefighting are made as underground filling stations of monolithic concrete.

Concrete floors must allow the passage of heavy-duty trucks. There is an assumption for one truck with a large capacity of 60 tons and 3 axles, each axle distributes the weight of 20 tons, and it is necessary to set the load on the wheel of 10 tons on an area of 20 cm x 60 cm.

Including a combined house for a pump with water for extinguishing a fire, as well as for a pump with drinking water / well pump and a water treatment plant with appropriate control equipment in a design similar to the design of the checkpoint.

The refueling area for filling underground steel refueling 2 x 10,000 liters for liquid fuel must be liquid-tight and connected to a coalescence separator. In addition, on the sides you need to place a house with a pump to install a pump unit with proper control. Also here it is necessary to provide loading by trucks of big loading capacity of 60 tons.

The performance and quality standards of the whole building must correspond to the functional Western European level. In relation to the long service life of all used building materials / products, great importance is attached to flawless processing. Insufficient and / or insufficiently processed building materials / products must be replaced with perfect ones.

All technical structures, such as, for example, complete electrical equipment, heating, ventilation and air conditioning, fire extinguishing systems. Water intake facilities, sewage treatment plants, refueling plants, pneumatic installations, gates, flue and heat dissipation systems, etc. the contractor must inspect / verify and accept an independent technical institute before applying for acceptance.

Electrical equipment included (including transformers; medium voltage, low voltage and compensation equipment; uninterruptible power supply installation; secondary electricity distribution equipment; gasket systems; feeders and risers; emergency lighting systems; clock installation; fire alarm system; fire alarm system; alarm system; computer equipment, including server, cable network of telecommunications installations, appliances and wiring devices, indoor lighting, outdoor lighting.

Heating; cooling / air conditioning (office space only); supply and exhaust ventilation; heat recovery; sanitary equipment; exhaust gas suction units; compressor installations; preparation of drinking and sewage, fire safety measures, etc .;

• Comparison and economic calculation of different heating, ventilation and air conditioning systems, etc.

• Design of fire-fighting systems (wall hydrants, sprinklers - where necessary, external hydrants, etc.) with their associated pipelines, tanks, booster pumps - to increase pressure, control systems and connection points with fire alarm devices.

## ORGANIZATION OF HOUSEHOLD SANITARY AND OTHER SERVICES WORKING AT THE ENTERPRISE

Sanitary facilities and devices for workers employed directly at the production site (dressing rooms, showers, restrooms, dining rooms, rooms for heating and drying workwear) are located in the existing administrative and household building in axes 7-10: E- L. The composition of sanitary facilities, the number of shower nets, taps, toilet bowls corresponds to the projected and existing number of employees, taking into account the sanitary characteristics of production processes and meets the requirements of SNiP 2.09.04-87 "Administrative and domestic buildings".

The premises of engineering and technical workers are located in the existing 2-storey administrative building in axes 1-2: D-I, separated from the production area by a fire partition.

Provision of workers with public catering is envisaged in the existing meal room with an area of 52 sq.m. in axes 7-8 / 9: K-L. The room is equipped with a washbasin, boiler, microwave oven, refrigerator, electric stove.

**Heating and heat supply**

An air heating system is designed on the site. For the needs of technology, 4 refrigerating machines are installed on the site, from which 246 kW of heat are supplied to the premises. Taking into account the heat input from the technological equipment and from the lighting, 356.75 kW of heat is supplied to the room in total.

Heat losses of the site, according to the working design of TOV Ergopak, amount to 368.2 kW.

The difference of 11.45 kW of missing heat is heated in the existing supply system P3.

The heat supply system of the air supply unit P3 is existing.

**Ventilation**

Ventilation at the site is mechanical supply and exhaust.

Air exchange at the site is calculated according to the required minimum amount of outdoor air per person, to dilute excess heat and local suction.

The inflow is carried out by the existing supply system P3. Supply air is distributed to the working area.

General exchange exhaust ventilation is carried out by the existing B15 exhaust system. Air is taken from the lower and upper zones of the site.

In summer, additional general ventilation is provided through the windows.

The site is designed with a local suction on the extrusion line, system B1.

Air is released into the atmosphere through a torch.

## WATER SUPPLY AND SEWERAGE

After the reconstruction of the production building, the total water consumption and wastewater disposal of the enterprise does not change. There is no industrial water consumption at the production site for disposable tableware.

In the compressor room, a sump 500x500x1000 (h) is designed to drain condensate from filters, dehumidifier, receivers and compressors, as well as in case of emergency situations and accidental spills. The effluent from the sump by a submersible electric pump GNOM 10-6 (Q = 10 m3 / h, H = 10m, N = 0.6 kW) is discharged into the existing utility sewerage network through a water seal.

The pipeline of the pressure industrial sewerage is designed from steel electric-welded pipes Ø 57x2.8 mm in accordance with GOST 10704-91.

The existing water sprinkler system for automatic fire extinguishing was designed earlier by VP Investspets Complex LLC.

The group of premises (production facilities and technological processes) according to the degree of fire hazard after the reconstruction of the production building has not changed.

Room group - 2;

The category of premises is "B".

The maximum consumption of compressed air for production is 950 m3 / h (15.8 m3 / min) at a pressure of 7-9 bar at consumers. Taking into account the coefficient of simultaneous operation of technological equipment, the compressed air consumption is 760 m3 / h (12.6 m3 / min). Compressed air consumption is uneven.

Supply of technological equipment for the production of disposable tableware with compressed air of purity class 2.4.3. according to the international standard ISO 8573-1, the project assumes from a screw compressor type DVK 125 Dalgakiran (Turkey), which provides air supply with a volume of 13.5 m3 / min (810 m3 / h) at a maximum pressure of 10 bar.

The production air supply scheme is supposed to be circular along the production building.

Compressed air pipelines are supplied to consumers from the compressor room along the walls and under the ceiling. At individual consumption points, air quality is ensured in accordance with the required technological requirements. At all points of air sampling, a compressed air preparation unit is provided, which includes a pressure reducing pneumatic valve complete with a pressure gauge, a safety pneumatic valve and a ball valve.

The design of the compressed air technological pipelines adopted in the project is intended to provide:

- safe and reliable operation within the standard period;
- maintaining the technological process in accordance with the design parameters;
- production of installation and repair work by industrial methods using mechanization means;
- the ability to perform all types of work on the control and heat treatment of welded seams and testing;
- prevention of formation of hydrate and other blockages in the pipeline.

**Cold supply system of the production site**

Technological consumers of cold in the production of disposable tableware are an extrusion line and automatic thermoforming lines.

To cool the molds of technological equipment, a refrigerant (water) with a temperature of + 10 ... + 15 ° C is used.

To satisfy the process refrigeration system in the cold, it is planned to install a refrigerating machine of the Angara Special EBHV 50.2 type with a cooling capacity of 242.4 kW and four refrigerating machines of the Angara ANG 35 type with a cooling capacity of 49.0 kW. Chillers are designed to operate on R407C freon.

Chillers are equipped with hydronic modules. The hydraulic module of each machine includes two circulation pumps, a buffer tank, an expansion tank, and a three-way control valve.

Refrigerating machines are supposed to be installed in close proximity to the technological equipment of the production site.

For the primary filling of the cooling systems with water and periodic replenishment of possible leaks, the project provides for the supply of chemically treated water from portable containers to the main pipeline of heated water.

**Vacuum pipelines and pneumatic transport**

With the help of vacuum and compressed air in the production of disposable tableware, the transportation of raw materials and crushed production waste is carried out within the production area.

For the transportation of polystyrene granules, the project provides for the laying of vacuum pipelines with a diameter of 150 mm from the supply tanks to the extrusion technological line.

For the transportation of crushed polystyrene waste, the project provides pneumatic pipelines with a diameter of 150 mm from crushers to silos of secondary raw materials. Waste transportation is provided by means of blowing fans built into the crusher.

The project provides for the use of galvanized steel air ducts with a diameter of 150 mm for the vacuum supply system and pneumatic transport of the section for the production of disposable tableware.

The laying of technological pipelines is carried out under the overlap of the building, with a slope that ensures their complete emptying into the workshop equipment or containers.

The design of technological pipelines adopted in the project is intended to provide:

- safe and reliable operation within the standard period;
- maintaining the technological process in accordance with the design parameters;
- production of installation and repair work by industrial methods using mechanization means;
- the ability to perform all types of work on the control and heat treatment of welded seams and testing;
- preventing the formation of ice, hydration and other plugs in the pipeline.

# 3. Structural part

## 3.1. Characteristics of construction.

The place of construction belongs to $3^{rd}$ C climatic region and characterized by the following data, represented in table 5.1.

- estimated ambient winter temperature – minus 20°C;
- characteristic snow load for u.t.s Lyubashovka of Odessa region – 1000 Pa;
- characteristic wind load for u.t.s Lyubashovka of Odessa region – 500 Pa;
- standard depth of frost penetration according to Construction Standards and Regulations СНиП 2.01.01-82 "Construction Climatology and Geophysics" – 90 cm;
- seismicity of the region – up to 6 points.

According to the data of engineering and geological survey, completed by LLC "KIEVGEOPLAN" in 2008, the foundations will be of panel-wall and pile types, which will depend on the type of structures.

**Geological conditions**

The geological section of the site is non-uniform and consists of the following engineering and geological elements:

- IGE 1 (ИГЭ) – Filled-up ground (medium-grained ground with layer thickness 0,4-0,5 m)
- IGE 2 – Solid loam with inclusions of rocks – 2,4-2,8 m.
- IGE 3 – Semisolid clay with inclusions of rocks – 5,6-5-6,2 v
- IGE 4 – Plastic yellow-brown clay with bands of soft sandy loam – 2,8-3,2 m.
- IGE 5 – Semisolid clay with bands of semisolid loam – 2,7-2,9 m.
- IGE 6 – Soft sandy loam with bands of fluid-plastic clay – 2,4-2,6 m.
- IGE 7 – Semisolid clay with yellow-brown or yellow-grey colour – 2,3-2,5 m.

The ground water was detected on the depth of 7,5-9,0 m.

According to the data of chemical analysis, the underground water is non-aggressive with respect to concrete.

The standard season depth of frost penetration into the soil is 0,9 m.

The site relief is flat, smooth, with total slope in direction to the riverbed of Chichikliya River.

The difference between ground elevations within the site frames is 2,0 m.

***Characteristics of the designed buildings and metal structures***

The main bearing structures of carcasses of the buildings are two-member columns, girders (the boiler house), transverse frames (for other buildings and structures), made of welded double tees.

The building stability is ensured by the systems of vertical and horizontal bracing and connections of frames.

The vertical and horizontal loads at the sides of buildings and structures are supported by bearing side framing. The posts of side framing have rigid connections with foundations.

The space rigidity and stability of buildings is ensured at the expense of joint operation of transverse frames, braces and vertical ties along columns and horizontal ties along flooring and roofs.

The roof girders are made of formed galvanized “Z”-type sections.

The wall girders are made of “Z”-type sections according to the detailed scheme of units.

According to the project, the floor girders will be made of rolled and welded double tees.

The roof of the building will be made of profiled sheets, on which heat insulation from mineral wool boards «ROCKWOOL» will be laid. The roof girders are made of formed galvanized “Z”-type sections.

***Connections***

All factory connections are represented with welded or erection joints on bolts with accuracy rating "B", strength grade 8,8 and on high-strength bolts with accuracy rating "B".

The circumferential seams in elements with length more than 2,0 m are carried out by means of automatic submerged-arc welding, other factory connections – by means of of semiautomatic gas-shielded arc welding. The welding materials for welding are to be selected from table 55 of Construction Standards and Regulations СНиП II-23-81* "Steel Structures".

For bolted connections it is planned to apply bolt with accuracy rating "B", strength grade 8,8 (according to State Standard (GOST) 7798-70*), with production requirements, which correspond to GOST 1759.4-87. The material of bolts is steel of grade 35X, according to GOST 4543-71*. The high-strength bolts M24-8gx110ХЛ and M27-8gx110ХЛ, which correspond to GOST 22353-77, are made of steel 40X "Select" (GOST 4543-71), have climatic version ХЛ, nuts M24 and M27 are to correspond to GOST 22354-77, washers M24 and M27 – to GOST 22355-77. The high-strength bolts, nuts and washers are produced according to technical requirements of GOST 22356-77.

The grades of steels of structure elements are accepted taking into the account types of structures for the climatic region 2$^{nd}$ C (t>-30C) and are specified in the list of elements, on schemes of metal structures and in units, according to table 50 of Construction Standards and Regulations СНиП II-23-81*.

It is envisaged that the flange connections will be made of 09G2S-15 (09Г2С-15) steel , according to GOST 19281-89. As of uniformity, the quality of steel is to meet requirements, listed in table 1. of "Recommendation on Calculation, Design, Production and Erection of Flange Connections of Steel Building Structures"

*Anticorrosive and fire protection*

The steps for anticorrosive protection are developed on the basis of Construction Standards and Regulations СНиП 2.03.11-85 "Anticorrosion Protection of Building Structures".

All works on anticorrosive protection are carried out with adherence of Standard 3.04.03-85 “Protection of Building Structures and Components from Corrosion” and GOST GOST 12.3.005-75 “Paint Works. General Safety Requirements”, GOST 12.3.016-87 “Construction. Anticorrosive Works”.

***Concrete and reinforced concrete structures***

The foundations for metal columns are reinforced concrete piles.

The basement for wall panels of sandwich type is monolith reinforced concrete with heat insulation extruded with polystyrene foam, mounted on outer sides of the basement.

The foundations for brick walls of staircases are of the strip type.

The staircases are made of prefabricated reinforced concrete elements, according to State Standard (GOST) GOST 8717.0-84, on metal bridgeboards and beams.

***Wall plating***

The external and internal wall plating is made of 0,5 mm thick profiled sheets and 60 μm thick polyester coating. The noncombustible mineral wool boards “ROCKWOOL” heat insulation for slabs is used for wall lining. The waterproof and steamproof films are used for creation of water and vapor barriers. The shaped decking is fixed to Z-type girders with the help of self-tapping screws. The longitudinal edges of sheets are butted with the help of rivets. The special battens with the same colour that of the wall plating are used for framing openings, angles etc.

***Roof covering***

The roof is made of profiled sheets with thickness 0,5 mm and polyester coating with thickness 60 μm, which are fixed to the top flange of the roof girder. The noncombustible heat insulation from boards “ROCKWOOL” for slabs is used for roof heat insulation. The roof sheets are fixed to girders with the help of self-tapping screws with tightening washers. The longitudinal edges of sheets are butted with the help of rivets. All butts of roof sheets, elements of abutment and framing are sealed with silicon joint sealant.

The storm drain is envisaged for water removal from the roof.

The roof drain system is connected to the storm water sewage system.

It is provided that waterproofer of structures will be surface, bitumen and membrane – sarking on bitumen mastic.

## 3.2. Foundations calculation

### 3.2.1 Calculation of the foundation under the column

It is accepted the pile foundation with bored reinforced concrete piles and monolithic pile cap.  Definition of the essential dimensions of pile foundations is held in accordance with the instructions and recommendations contained in the rules [4].

Calculation of pile foundation is made for the most loaded column. Values of loads on the foundation:

$N$=1954,3 kN

$M$=8,3 kN ·m

$Q$=6,6 kN

- Depth of the pile cap laying

It is appointed according to the constructive requirements without taking into account seasonal freezing of soils, engineering-geological features of the construction site. In the first approximation the height of the pile cap is assigned on 0,4 ÷ 0,5 m greater than the required depth of columns laying in the foundation $h_f$ = 0,7 m.

$d_k=h_f+(0,4\div0,5)$m

$d_к$=0,7+0,5=1,1m

Pile cap's dimensions in height should be taken multiple to 0,1m.

Accept the height of pile cap $d_1$=$d_к$=1,2m.

The obtained value of the depth of the $d_k$ = 1.2 m is deposited in a scale in the scheme of planning and absolute mark of the pile cap bottom is preliminary established equal to 143.77 m.

- Pile laying into a bearing a layer of soil

Pile laying $h_з$ in supporting (bearing) layer of soil is taken 0,5 m (for the crushed stone soil) and approximate design pile length $h_P$ is set by the scheme, which is calculated as the distance from the bottom of the proposed foundation pit to the lower end of the pile.

Thus, making laying of piles in coarse crushed stone layer of soil on 0.5 m, we will obtain:

$h_p$=$h_1$+0,5=4,7+0,5=5,2m

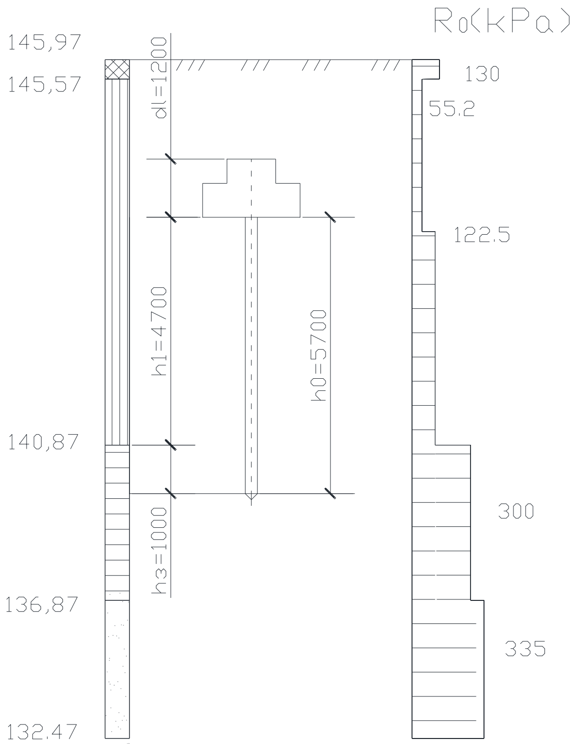


*Fig.3.1. Design scheme of pile.*

Choose bored pile of circular cross section Ø600мм and height of 6m.

Fixing of upper ends of piles in pile cap is taken equal to 30cm (5cm pile and 25cm reinforcement extensions).

Taking this into account design length of the pile is calculated again:

$h_P = h_{св} – 0,3 = 6 – 0,3 = 5,7$m.

The values of the design length of the pile are $h_P$=5,7 m and are set on geological section.

The actual penetration of the pile in the supporting layer of coarse crushed stone soil:

$h$=5,7–4,7=1,0m >0,5m

Consequently, the pile of this brand satisfies the condition.

- Bearing capacity of bearing piles from the strength condition of soil $F_d$

Bearing capacity of bearing piles is calculated by the formula:

$$F_d = \gamma_c \cdot R \cdot A,$$

where $\gamma_c$ is factor of pile working conditions in the ground, $\gamma_c$ =1;

$R$ is design resistance of the soil below the bottom end of the pile, kPa;

For coarse crushed stone soil R=20000kPa;

$A$ – area of cross section of pile, m$^2$;

$$A = 3{,}14 \cdot 0{,}3^2 = 0{,}28 m^2$$

$$F_d = 1 \cdot 20000 \cdot 0{,}28 = 5652 kN$$

- Design load on a pile for soil strength conditions:

$$Ð = \frac{F_d}{\gamma_k},$$

where $\gamma_k$ is safety factor, assigned in dependence of the method of bearing capacity of piles determination and equal to $\gamma_k$=1,4.

$$P = \frac{5652}{1{,}4} = 4037{,}2 kN$$

Bearing capacity of pile acting in compression at the material $F_{dm}$:

$$F_{dm} = \varphi \cdot \gamma_c (\gamma_{cb} \cdot \gamma^1{}_{cb} \cdot R_b \cdot A_b + R_{sc} \cdot A_s),$$

where $\varphi$ is buckling factor, accepted $\varphi$=1;

$\gamma_c$ is factor of working conditions for piles with the cross section > 0,2m, accepted equal to $\gamma_c$=1;

$\gamma_{cb}$ is factor of working conditions for bored piles, $\gamma_m$=0,85;

$\gamma^1_{cb}$ is dependent from the way of pile concreting: at dry concreting $\gamma^1_{cb}$=1

$R_b$– design resistance of concrete at axial compression taken for piles from concrete of class B25 $R_b$=14,5MPa;

$R_{sc}$ – design compressive resistance accepted for reinforcement of class

A-300 $R_{sc}$=270MPa;

$A$ – area of transversal cross section of working reinforcement, m$^2$;

$$A_a = 6 \cdot 3{,}14 \cdot 0{,}02^2 / 4 = 0{,}00188\, m^2$$

$F_{dm}$=1·1·(0,85·1·14500·0,28+270000·0,00188)=3958,6kN

In the calculation lowest value of obtained values $P$, $F_{dm}$, is accepted, where $P$ =3958,6 kN.

- Determination of piles amount in foundation

$$n = \frac{N^P}{P} \cdot 1{,}2,$$

where 1,2 is coefficient increasing amount of piles in foundation on 20%, including the action of bending moment and shearing force;

$N_P$ is design value of the vertical load for safety factor at load $\gamma_f$ =1,1;

$N^P$=12954,3·1,1=14249,7 kN

$$n = \frac{14249{,}7}{3958{,}6} \cdot 1{,}2 = 3{,}9$$

Accepted $n$=4.

-Pile cap construction

There is made displacement of piles and pile cap size definition in plan. Distance between the trunks of bored piles is taken not less than 1m. Pile caps dimensions in plan are multiple to 0.1 m.

The distances between the axes of piles are constructively accepted 1700mm. The distance from the edge of the pile cap to the outer edge of piles is 200mm.

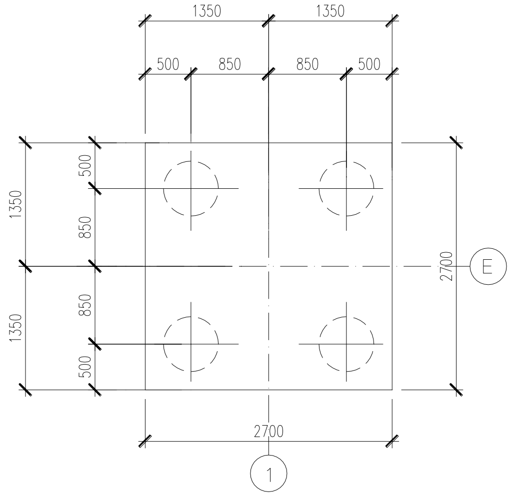


*Fig.3.2. Scheme of piles position in foundation.*

- Check of the load on the corner foundation piles, as the most loaded, is made as follows:

$$N_{cв}{}^{\frac{max}{min}} = \frac{N^P + G}{n} \pm \frac{M \cdot x}{\sum x_i^2},$$

where $x$ is distance from main axis to the axis of corner pile, $x$=0,85,;

G is design load of own weight of pile cap and soil on its steps, kN, roughly defined at γ f = 1,1 as:

$$G = \gamma_f \cdot A_P \cdot \gamma \cdot d_l$$

$$G = 1{,}1 \cdot 2{,}7 \cdot 2{,}7 \cdot 20 \cdot 1{,}2 = 192{,}5 \ kN$$

$M$ – design value of bending moment with respect to the main axis of the pile cap base, kN*m at γ f = 1,1, defined as:

$$M = M^P + Q^P \cdot d_l$$

$$M = 80{,}3 \cdot 1{,}1 + 69{,}6 \cdot 1{,}2 \cdot 1{,}1 = 180{,}2 kN \cdot m;$$

$\sum x_i^2$ – sum of squares of distances from the main axis to the axis of each pile, $m^2$;

$$\sum x_i^{\ 2} = 0{,}85^2 \cdot 4 = 2{,}89 m^2$$

$$N_{св}^{\max} = \frac{14249{,}7 + 192{,}5}{4} + \frac{180{,}2 \cdot 0{,}85}{2{,}89} = 3663{,}6kN$$

$$N_{св}^{\min} = \frac{14249{,}7 + 192{,}5}{4} - \frac{180{,}2 \cdot 0{,}85}{2{,}89} = 3557{,}6kN$$

*Check:*

$N_{св}^{max} \leq 1{,}2P$

3663,6≤1,2·3958,6=4750,32 – condition is satisfied.

$N_{св}^{min} > 0$

3605,2>0 – condition is satisfied.

As both conditions are satisfied we accept 4 piles in the foundation.

**3.2.2. Calculation of reinforced-concrete pile cap on column punching.**

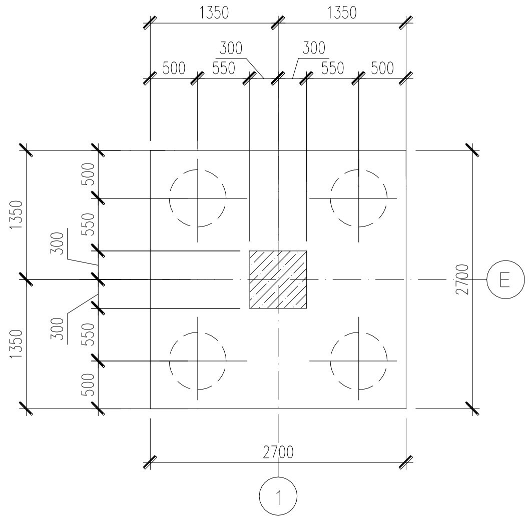


*Fig.3.3. Pile foundation with a pile cap socket.*

There is held a pile cup check on column punching by the pyramid, the sides of which go from outer edges of the column to inner edges of piles and are inclined to the horizontal not more than angle corresponding to the pyramid in $c$=0,4·$H_0$.

Calculation formula is:

$$N \le 2R_{bt} \cdot H_0 \left[ \alpha_1 \left( h_c + c_2 \right) + \alpha_2 \left( b_c + c_1 \right) \right],$$

where $N$ is estimated punching force equal to doubled sum of the reactions of all piles, located on the most loaded side from the axis of column outside of the punching pyramid's lower base limits. Calculated by the efforts acting in the plane of foundation top, kN, taking into account safety factor of the loading in the calculation by the first group of limiting states.

$H_0$ is working height of the pile cap taken $H_0$=1,5m.

$h_c$, $b_c$ is length and width of the column cross section, $h_c$=0,6m, $b_c$=0,6m.

$c_1$, $c_2$ are distances from the column's side plane to the plane of the nearest pile's edge taken $c_1$= $c_2$=0,25m.

$\alpha_1$, $\alpha_2$ are coefficients taken in dependence of the parameters $k_1=c_1/H_0$, $k_2=c_2/H_0$

$k_1= k_2$=0,25/1,5=0,17< 0,3, that's why $k_1= k_2$=0,3 and $\alpha_1=\alpha_2$=5,24.

$R_{bt}$ is a design resistance of concrete to axial tension, kPa, for specific state of I group adopted taking into account coefficient of working conditions $\gamma_{в2}$=1,1.

For concrete B20 $R_{bt}$=900·1,1=990kPa.

Reaction of one pile of the foundation could be determined as:

$$P_{ф} = \frac{N^p + G_1}{n} = \frac{14249,7 \cdot 1,1 + 192,5 \cdot 1,1}{4} = 3971,6kN$$

Outside of the punching pyramid's lower base limits there are 2 piles in this case so the calculated punching power is:

$$N = P_{ф} \cdot n \cdot 2 = 3971,6 \cdot 2 \cdot 2 = 15886,4kN$$

In the right part of condition we have:

$$2 \cdot 990 \cdot 1,5 \cdot [5,24(0,6 + 0,25) + 5,24(0,6 + 0,25] = 26456,8kN$$

$$26456,8 > 15886,4kN$$

Condition is satisfied. Therefore, punching of the pile cap's body by the column will not happen.

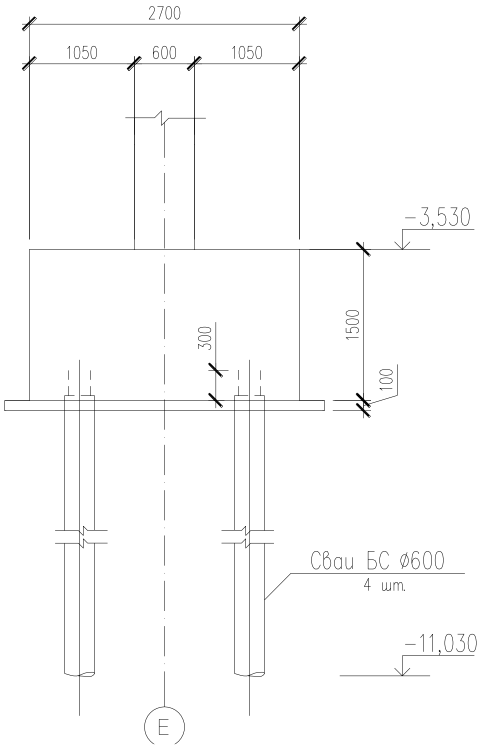


*Fig.3.4. Pile foundation with a pile cap socket section.*

**3.2.2. Calculation of pile foundation on the combined action of vertical and horizontal loads and moments (on deformations).**

According to normative documents pile foundations from piles acting like column pile should not be calculated on deformations (on settlement).

Calculation of the piles on the combined action of vertical and horizontal forces and moments is produced in accordance with the scheme shown on Figure 3.1.5, and includes test on compliance with conditions for admissibility of the calculated horizontal displacements of the pile head.

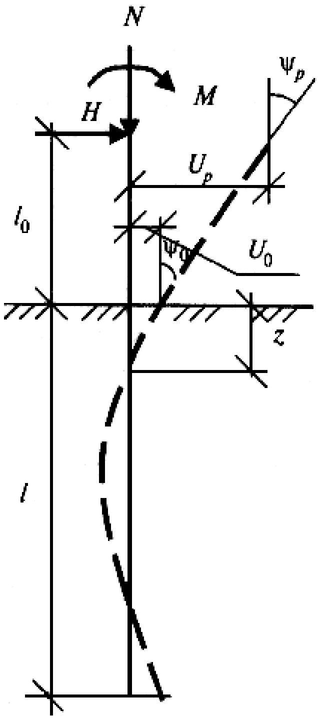


*Fig.3.5. Scheme of loadings of pile.*

$$u_p \leq u_u,$$

where $u_p$ is estimated value of horizontal movement of the head pile, m;

$u_u$ is limit value of respective horizontal movement of pile head, m, set in the design task for design of building or structure, $u_u$=0,01m.

Moment of inertia of the pile's transversal cross-section:

$$I = \frac{b \cdot h^3}{12} = \frac{0,6 \cdot 0,6^3}{12} = 0,01m^4$$

Stiffness of the pile's transversal cross-section in bending:

$$EI = 3,0 \cdot 10^7 \cdot 0,01 = 3 \cdot 10^5 kPa \cdot m^4$$

Reduced width of pile:

$$b_p = 1,5d + 0,5m = 1,5 \cdot 0,6m + 0,5m = 1,4m$$

*K* is a proportionality constant, kN/m$^4$, accepted in dependence on the type of soil surrounding the pile.

To define proportionality constant *K* one should determine depth $l_k$, calculated from a pile cap foot.

$$l_k = 3,5d_1 + 1,5ì$$

$$l_k = 3,5 \cdot 0,6 + 1,5 = 3,6m$$

As in limits of length $l_k$ there is one layer of soil the amount of a coefficient $K$ is determined according to table Д.1 [4], $K$=8000kN/m$^4$.

$\alpha_\varepsilon$ – coefficient of deformation, m$^{-1}$, defined by formula:

$$\alpha_\xi = \sqrt[5]{\frac{Kb_p}{EI}}$$

$$\alpha_\varepsilon = \sqrt{\frac{8000 \cdot 1,4}{3 \cdot 10^5}} = 0,19m^{-1}$$

Modified value of a pile immersion in the ground:

$$\bar{l} = \alpha_\varepsilon \cdot h_p$$

$$\bar{l} = 0,19 \cdot 5,7 = 1,1m$$

Design value of horizontal displacement of piles in the level of the pile cap's foot $u_p$, m, is defined by formula:

$$u_p = u_o + \varphi_o l_o + \frac{Hl_o^3}{3EI} + \frac{Ml_o^2}{2EI},$$

where $H$ and $M$ are design values of shearing force, kN, and bending moment, kN·m, acting on a pile had;

$l_o$ is the length of pile, m, equal to the distance from the foot of the pile cap to the ground surface under the pile cap;

$u_o$ and $\varphi_o$ are horizontal displacement, m, and angle of rotation of pile's transversal cross-section, rad, in the level of the pile cap's foot.

Horizontal displacement $u_o$ and angle of rotation $\varphi_o$ are defined by formulas:

$$u_o = H_o \cdot \varepsilon_{нн} + M_o \cdot \varepsilon_{нм}$$

$$\varphi_o = H_o \cdot \varepsilon_{мн} + M_o \cdot \varepsilon_{мм},$$

where $H_o$ and $M_o$ are design values correspondingly of shear force, kN, and bending moment, kN•m, in investigated cross section of a pile accepted equal to $H_o$=$H$=69,6kN and $M_o$=$M$+$H$·$l$=80,3+69,6·4,7=407,4 kN•m;

$\varepsilon_{нн}$- horizontal movement of the cross section, m/kN, from force $H_o$;

$\varepsilon_{нм}$- horizontal movement of the cross section, m/kN, from moment $M_o$;

$\varepsilon_{MH}$- angle of rotation of the cross section, 1/kN, from force $H_o$;

$\varepsilon_{MM}$- angle of rotation of the cross section, 1/ kN•m, from force $M_o$;

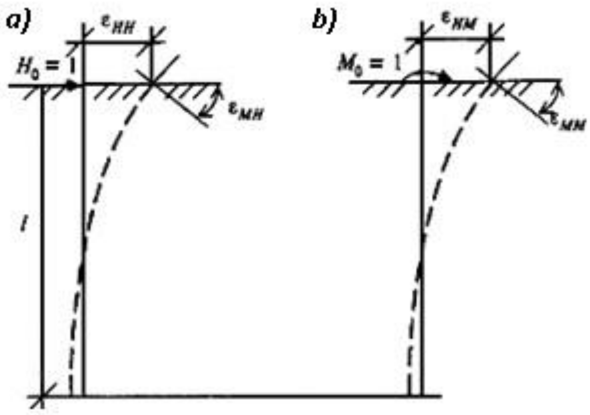


*Fig.3.6. Scheme of pile's displacement in soil: a) for $H_0$; b) for $M_0$*

Displacements $\varepsilon_{HH}$, $\varepsilon_{HM}$, $\varepsilon_{MH}$ and $\varepsilon_{MM}$ are calculated by formulas:

$$\varepsilon_{HH} = \frac{1}{\alpha_\varepsilon^{\,3} EI} \cdot A_o$$

$$\varepsilon_{MH} = \varepsilon_{HM} = \frac{1}{\alpha_\varepsilon^{\,2} EI} \cdot B_o$$

$$\varepsilon_{MH} = \varepsilon_{HM} = \frac{1}{\alpha_\varepsilon EI} \cdot C_o ,$$

where $A_o$, $B_o$ and $C_o$ are non-dimentional coefficients, accepted by Д.2 in dependence on the reduced depth of the pile immersion in the ground $\bar{l}$.

$$\varepsilon_{HH} = \frac{1}{0{,}19^3 \cdot 3 \cdot 10^5} \cdot 2{,}441 = 0{,}0012$$

$$\varepsilon_{MH} = \varepsilon_{HM} = \frac{1}{0{,}19^2 \cdot 3 \cdot 10^5} \cdot 1{,}621 = 0{,}00015$$

$$\varepsilon_{MM} = \frac{1}{0{,}19 \cdot 3 \cdot 10^5} \cdot 1{,}751 = 0{,}00003$$

$$u_o = 69{,}6 \cdot 0{,}0012 + 407{,}4 \cdot 0{,}00015 = 0{,}145 m$$

$$\varphi_o = 69{,}6 \cdot 0{,}00015 + 407{,}4 \cdot 0{,}00003 = 0{,}02 m$$

$$u_p = 0{,}145 + 0{,}02 \cdot 4{,}7 + \frac{69{,}6 \cdot 4{,}7^3}{3 \cdot 3 \cdot 10^5} + \frac{80{,}3 \cdot 4{,}7^2}{2 \cdot 3 \cdot 10^5} = 0{,}0078\,m \prec u_u = 0{,}01m$$

Condition is satisfied, therefore, the horizontal movements of the piles heads are allowed.

### 3.2.3. Calculation of the strip pile foundation under the stiffening diaphragm.

Calculation of the strip pile foundation under the stiffening diaphragm is based on collecting loads acting on 1 running meter of diaphragm. Stiffening diaphragm is a bearing structure of the building.

The load on 1 running meter is 3781.06 kN/m.

Material of piles is concrete of class B25.

$R_b$ is a design strength of concrete on axial compression $R_b$=14,5 MPa.

Material of the pile cap is concrete of class B20.

$R_b$ is a design strength of concrete on axial compression $R_b$ = 11,5 MPa.

### 3.2.4. A depth of the pile cap's base.

The height of the pile cap is taken constructively by the results of calculation of the pile foundation under the column equal to 1.8 m. The depth of the pile cap's base

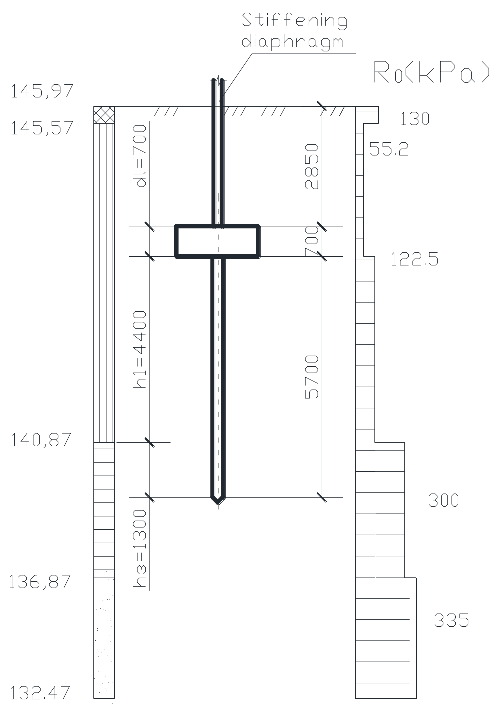


*Fig.3.7. Design scheme of pile.*

**3.2.5. Deepening pile in the bearing layer of soil.**

Taking into account deepening piles into mottled clay of soil at 0.5 m we will get:

$h_p = h_1 + 0.5 = 3.6 + 0.5 = 4.1$ m.

Choose a bored pile with length 6m and Ø500mm. Building-in upper ends of the piles in the pile caps is assumed to be 30 cm (5 cm of pile and 25 cm elongations of reinforcement).

Determine the design pile length one more time:

$h_P = h_{св} - 0.3 = 6 - 0.3 = 5.7$ m.

The values of the design length of piles $h_P = 5.7$ m are marked on the design scheme.

The actual penetration of the pile in the bearing layer of mottled clay:

$h = 5.7 - 4.1 = 1.6$ m> 0.5 m.

Therefore the pile of this brand is correct.

**3.2.6. Bearing capacity of bearing piles under the strength condition of soil.**

Bearing capacity of bearing piles is determined by the formula:

$$F_d = \gamma_c \cdot R \cdot A,$$

where $\gamma_c$ is coefficient of piles working conditions in the ground , $\gamma_c = 1$;

*R* is design resistance of the soil below the lower end of the pile, kPa;

For mottled clay R=20000kPa;

*A* is a cross section area of pile, $m^2$;

$$A = 3{,}14 \cdot 0{,}25^2 = 0{,}20 m^2$$

$$F_d = 1 \cdot 20000 \cdot 0{,}20 = 3925 kN$$

**3.2.7. Design load applied to the pile under soil strength conditions.**

$$Đ = \frac{F_d}{\gamma_k},$$

where $\gamma_k$ is reliability coefficient, appointed according to the determination method of piles bearing capacity and equal $\gamma_k = 1.4$.

$$P = \frac{3925}{1,4} = 2803,6kN.$$

**3.2.8. Bearing capacity of piles working on compression by the material.**

$$F_{dm} = \varphi \cdot \gamma_c (\gamma_{cb} \cdot \gamma^1{}_{cb} \cdot R_b \cdot A_b + R_{sc} \cdot A_s),$$

where $\varphi$ is buckling coefficient, taken $\varphi$=1;

$\gamma_c$ is a coefficient of working conditions; for piles with cross section ≥ 0.2m is taken $\gamma_c$=1;

$\gamma_{cb}$is coefficient of concrete working conditions, for bored piles $\gamma_m$=0,85;

$\gamma^1{}_{cb}$ depends on the method of borehole digging: at dry concreting $\gamma^1{}_{cb}$=1;

$R_b$ is design resistance of concrete to axial compression taken for the piles of concrete class B25 $R_b$=14.5MPa;

$R_{sc}$ is design resistance on compression of reinforcement of class A-300, $R_{sc}$=270MPa;

$A$ is a cross-sectional area of working reinforcement, m$^2$;

$$A_a = 6 \cdot 3{,}14 \cdot 0{,}02^2 / 4 = 0{,}00188\, m^2$$

$F_{dm}$=1·1·(1·0,85·14500·0,2+270000·0,00188)=2972,6$kN$

In the calculation the lower obtained values P, $F_{dm}$ are taken, where $P$ =2803.6$kN$.

**3.2.9. Determination of piles quantity per 1 running meter of foundation.**

$$n = \frac{N^P}{P} \cdot 1.2,$$

where 1.2 is coefficient that increases the number of piles in the foundation by 20% because of the bending moment and shear force actions;

$N^P$ is an estimated value of the vertical load at safety factor on load $\gamma_f$ =1.1;

$N^P$=3781.06·1.1=4159.2$kN$

$$n = \frac{4159.2}{2803.6} \cdot 1.2 = 1.8$$

Final number of piles per 1m of basement is accepted equal to $n$=2.

**3.2.10. Erection of pile cap.**

There is made allocation of piles and determination of the pile cap's sizes in the plan.

Distances between the trunks of bored piles are taken not less than 1m. Pile cap's dimensions in plan are multiple to 0.1 m.

Distances between pile axes are accepted 1500mm. The distance from the edge of the pile cap to the outer edge of pile is set 200mm.

The scheme of the pile cap and its basic dimensions are shown on Figure 3.2.8.

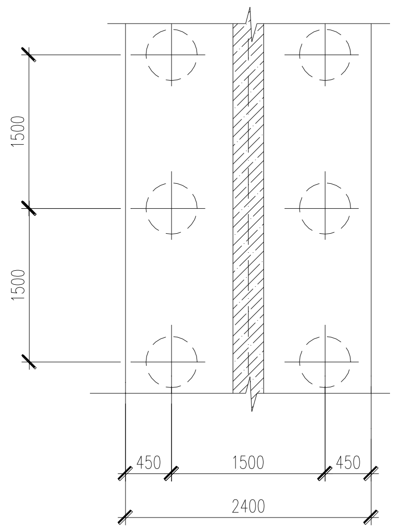


*Fig.3.8. Scheme of piles arrangement in strip foundation.*

**3.2.11. Checking of load acting on one pile of foundation.**

Checking is made by the formula:

$$N_{св} = \frac{N^p + G}{n} \leq 1.2P \quad ,$$

where G is design load of own weight of pile cap and soil on its steps, kN, roughly defined with $\gamma_f$=1.1 as:

$$G = \gamma_f \cdot A_P \cdot \gamma \cdot d_l$$

$$G = 1.1 \cdot 2.4 \cdot 1.5 \cdot 20 \cdot 1.5 = 118.8 kN$$

$$N_{св} = \frac{4159.2 + 118.8}{2} = 2139\, kN$$

Checking of condition fulfillment:

$N_{св} \leq 1.2P$

$2139kN \leq 1.2 \cdot 2803.6kN = 3364.3kN$

2139kN≤3364.3kN

As the condition is satisfied we accept two piles on the 1m of basement.

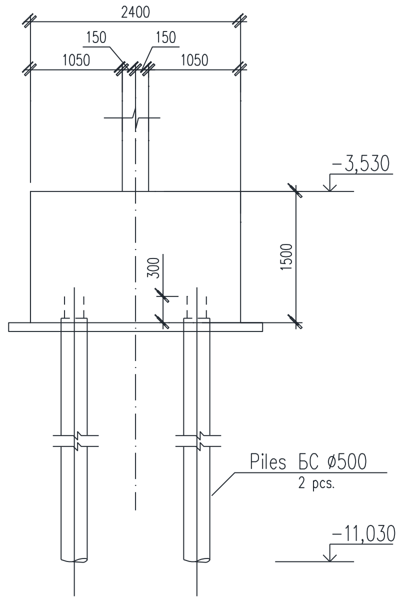


*Fig.3.9. Strip pile foundation.*

### 3.2.12. Calcualtion of pile cap's reinforcement.

Assign pile cap reinforcement in accordance to design requirements:

$$A_S = A_S^{'} = 0.0005 b_f^{'} h = 0.0005 \cdot 1600 \cdot 1500 = 1200\, mm^2.$$

Accept neat pile cap's edges 8ø14 AIII ( $A_S = A_S^{'} = 1231\, mm^2$ ) as mesh C3.

## 4. Technical maintenance of building and facilities.

### 4.1 General provision

Currently, two systems of technical maintenance of buildings and structures are used as a set of interconnected organizational and technical measures to establish the technical condition of buildings and structures, to carry out preventive measures and repairs to structures and equipment, carried out in strict terms, to ensure the safety and operational suitability, to prevent premature wear and tear prevention:

-the system of maintenance and repair of residential buildings and objects of communal and socio-cultural purposes in accordance with VSN 58-88 (p) Regulations on the organization, reconstruction, repair and technical inspection of residential buildings of public utilities and social and cultural facilities;

-system of preventive maintenance of buildings and structures for industrial purposes.

Technological operation (maintenance) of structures and engineering systems provides for the necessary measures to create design operating conditions for all elements of buildings and structures.

Technical operation is a set of technical measures that ensure the trouble-free operation of all elements and systems of buildings and structures during their standard service life.

The activities of technical operation include work to ensure regulatory regimes and parameters, regulation and refinement of equipment and building systems and landscaping, identification of faults that have appeared in them, elimination of minor damages in the process of monitoring. The complex of these measures covers the following inspections and repairs:

general inspection;

partial inspection;

extraordinary inspection;

current preventive maintenance;

current unforeseen repairs;

- selective and comprehensive overhaul.

The main purpose of inspections and repairs in buildings and structures is partial and complete restoration of the wear of individual structural elements. engineering equipment and decoration. They should be carried out periodically in a planned manner and within a strictly specified time frame.

In the process of conducting inspections and identifying defects, damage to structural elements or their protective coatings, it is necessary to establish the main cause of these defects, eliminate it, and only after that proceed with the repair and restoration work.

From the essence of technical operation, the following tasks of the operation service follow:

firstly, leaving, i.e. constant maintenance of structures and structural elements in good condition, compliance with the required temperature and humidity conditions in the premises, timely maintenance of engineering equipment and technical systems.

secondly, the control of the parameters characterizing the operational suitability of buildings and structures, carried out with the help of special devices and tools according to approved methods;

thirdly, the planned conduct of inspections, current and major repairs of buildings and structures.

**Monitoring the technical condition of buildings and structures.**

Monitoring of the technical condition of buildings and structures is carried out for: monitoring the technical condition of buildings and structures and timely taking measures to eliminate emerging negative factors leading to the deterioration of this condition;

- identification of objects on which there have been changes in the stress-strain state of load-bearing structures and for which an examination of their technical condition is necessary;
- ensuring the safe functioning of buildings and structures for due to timely detection at an early stage of negative changes in the stress-strain state of structures

and soils of foundations, which may entail the transition of objects to partially functional or in emergency condition;

-tracking the degree and rate of change in technical condition object and taking, if necessary, emergency measures to preventing its collapse.

To determine the tasks of monitoring the technical condition specific building (structure), develop a program for monitoring, in which, along with listing the types of work, establish system and frequency of observations, taking into account the technical condition facility, as well as the total duration of monitoring. The program monitoring is agreed with the customer.

When choosing an observation system, take into account the purpose of monitoring, as well as the speed of the processes and their change during time, duration of measurements, measurement errors, including due to changes in the state of the environment, as well as the influence of interference and anomalies of natural and technogenic character. Methodology and system scope observations during monitoring, including measurements, should provide the reliability and completeness of the information received for the preparation the executor of a reasoned opinion on the current technical condition object (s).

During long-term observations and when changing external conditions, it is necessary to ensure that changes in conditions are taken into account and compensatory corrections (temperature, humidity, etc.) for measuring devices.

As a result of each stage of monitoring, there should be sufficient information has been obtained to prepare a reasonable conclusions on the current technical condition of a building or structure and issuing a short-term forecast about its condition for the next period.

The initial stage of monitoring the technical condition of buildings (structures), except for general monitoring of technical condition buildings (structures), is an examination of their technical condition. On Organization of the provision of state and municipal services: practice of buildings and structures operation.

At this stage, the categories of the technical condition of buildings are established (structures), fixing structural defects, for a change in state, which (as well as for the occurrence of new defects) will be carried out observations during monitoring.

If you receive data at any stage of monitoring, indicating a deterioration in the technical condition of the entire structure or its elements that can lead to the collapse of the building (structure), the monitoring organization should immediately report the current situation, including in writing, the owner facility, operating organization, local executive bodies authorities, territorial bodies of the department for civil defense affairs, emergency situations and elimination of consequences of natural disasters.

It is accepted to share the general monitoring of technical condition buildings and structures and monitoring the technical condition of buildings and structures that are in limited serviceable or emergency condition.

General monitoring of the technical condition of buildings (structures) carried out to identify objects, change the stress-strain the state of which requires examination of their technical condition. When general monitoring, usually instead of a survey technical condition of buildings (structures) in full, carry out visual inspection of structures in order to roughly assess the category technical condition, measure the dynamic parameters of specific buildings (structures).

If, according to the results of a rough estimate, the category of technical the state of the building (structure) complies with the normative or operable technical condition, then repeated measurements dynamic parameters are carried out after two years. If the results repeated measurements of dynamic parameters, their changes do not exceed 10%, then the next measurements are carried out after another two years.

If, according to the results of a rough estimate, the category of technical the state of the building (structure) corresponds to a partially workable or an emergency state, or if, when re-measuring dynamic parameters of the building (structure), the measurement results differ by more than 10%, then the technical condition of such a building (structure) is subject to mandatory unscheduled examination. Based on the overall monitoring the technical condition of buildings (structures) performer draws up a conclusion on the stage of general monitoring technical condition of buildings (structures) and conclusions on the technical the state of each building (structure), on which the general technical condition monitoring (see Appendix 10).

When monitoring the technical condition of buildings (structures), category of technical condition of which corresponds to a limited extent operable or emergency state, control the processes.

Flowing in the structures of buildings (structures) and soil before execution work on the restoration or strengthening of facilities and during suchworks.

At each stage of monitoring the technical condition of structures buildings (structures) and soil carry out the following works:

- determine the current dynamic parameters of the object and compare them with the parameters measured at the previous stage;
- record the degree of change of previously identified defects and damage to the structure of the object and identify newly appeared defects and damage;
- repeat measurements of deformations, rolls, deflections, etc. and compare them with the values of similar quantities obtained at the previous stage;
- analyze the information received at this stage of monitoring and make a conclusion about the current technical condition of the object.

Form of conclusion on the technical condition of the object located in limited working or emergency condition.

A special role in the rules of technical maintenance of buildings and structures are assigned to monitoring the technical condition of buildings and structures falling into the zone of influence of new construction, reconstruction or natural and man-made impacts that implement based:

- determination of absolute and relative values of deformations structures of buildings (structures) and comparing them with calculated and acceptable values;

- identifying the causes and the degree of danger of deformations for normal operation of facilities;
- taking timely measures to combat emerging deformations or to eliminate their consequences;
- refinement of design data and physical and mechanical characteristics soils;
- clarification of design schemes for various types of buildings (structures) and communications;
- establishing the effectiveness of taken preventive and protective measures;
- clarification of the regularities of the process of displacement of soil rocks and dependence of its parameters on the main influencing factors.
- Scientific and technical support and monitoring of new construction or reconstruction of objects is allowed to be carried out.

When monitoring the technical condition of buildings (structures), falling into the zone of influence of new construction or reconstruction objects arranged in an open way use data (radius zones of influence, additional deformations.

Determination of the values of the expected maximum displacements and deformations of the earth's surface and expected displacements and deformations in points of the displacement trough in the underground method of building an object carried out in accordance with Appendix 14.

Total duration the process of displacement of the earth's surface over the produced underground production and the period of dangerous deformations are determined in accordance with Appendix 11.

## 5. Construction technology.

### 5.1. Strengthening and restoration of foundations during reconstruction

All methods of strengthening and restoring bases can be divided into two main groups:

- strengthening by fixing soils;
- increasing the strength of the foundations by deep soil compaction.

Strengthening the base by fixing soils consists in binding soil particles. Fastening increases mechanical strength, water resistance, longevity. Depending on the technology of consolidation and the processes occurring in the soil, the methods of consolidation are divided into three types: chemical, physicochemical and thermal.

The essence of chemical methods is that low-viscosity solutions are injected through the perforated pipes (injectors) previously immersed in it. Being in the soil, the solutions enter into a chemical reaction with the soil and, hardening in it, improve the chemical properties of the base.

Chemical methods are divided into two groups, the first includes methods using silicate solutions and their derivatives, the second - methods using organic polymers (acrylic, carbamide, resorcinol-formaldehyde, furan resins, etc.).

The most common are silicatization methods. The material for silicatization is liquid glass - a colloidal solution of sodium silicate.

With single-solution silicatization, a gel-forming solution is injected into the soil, consisting of two or three components: solutions of sodium silicate and a hardening reagent (solution of acids, organic compounds). As a result of the ongoing reaction, the soil is cemented with silicic acid gel.

With two-solution silicatization, the fixing process is reduced to alternate injection of sodium silicate solution and potassium chloride solution into the soil. In the process of interaction of solutions, a hydrogel of silicic acid is formed. The sand becomes waterproof after injection.

In gas silicatization, carbon dioxide is used as a sodium silicate hardener. Gas is injected into the ground for its preliminary activation. After that, sodium silicate is injected, and then carbon dioxide is injected into the soil. The method is used for sandy and subsiding loess soils, as well as soils with a high content of organic matter. Fixed sands acquire strength 0.8 ... 1.5 MPa, and loess soils 0.8 ... 1.2 MPa.

Electrosilicization uses a combined application of direct electric current and silicate solutions. The method is intended for fixing waterlogged fine-grained soils and sandy loams, as well as loess soils, into which liquid glass penetrates with difficulty

When aerosilicating soils, compressed air is used, which is poured into the soil together with a fixing solution of liquid glass. The supply of compressed air makes it possible to obtain in the soil radially directed from the injector ray-shaped sections of the fixed soil.

For large volumes of pumping of plugging materials, clay-silicate solutions are used, which are mixtures of aqueous solutions of highly dispersed clays with a small addition of sodium silicate. Sodium silicate injects the formation of an elastic gel in the pores of the soil, which ensures the waterproofing of the soil mass.

Other chemical methods include ammonization and resinization.

During ammonization, gaseous ammonia is injected into the soil under low pressure. The method allows to impart non-subsidence properties to loess soils.

During resinization, aqueous solutions of synthetic resins (carbamide, epoxy, furan, etc.) are injected into the soil together with hardeners (acids, acidic salts). After interaction with hardeners, the resin polymerizes. Resinization is used when fixing sand with a filtration coefficient of 0.5 ... 45 m3 / day. and loess soils. The soils become waterproof and have compressive strength up to 1 ... 5 MPa.

The choice of the method and zones of chemical soil consolidation depends on the characteristics of the foundation, the shape and size of the foundation, and the existing loads. Zones of fastening in the plan can be tape, solid, discontinuous, circular and curvy.

Depending on this and the properties of the soil, the distance between the injectors and their position (vertical, inclined, horizontal, combined) are determined

The physicochemical methods of soil consolidation include cementation, soil-cementation, bituminization and clay formation.

During cementation, a cement, cement-sand or cement-clay mortar is injected into the soil through injectors. The addition of clay up to 5% improves the quality of work. The method is used to fix sandy, coarse-grained soils and fractured rocks.

During soil cementation, soil-cement (silt-cement) piles are arranged to strengthen the foundations. For the installation of piles, the soil in the drilled well is mixed with the binder without removing it from the well. The method is used to consolidate soft soils when erecting new buildings near operated buildings, creating underground structures in soft soils (for example, silt piles, soil-cement strip foundations, etc.), installing anti-seepage curtains, etc.

In clay formation, clay solutions are used to fill wells. It is used in fractured rocks.

In bituminization, heated bitumen or cold bitumen emulsion is used as an injected substance. The method is recommended for sandy soils with filtration coefficients of 10 ... 50 m / day. Due to the complexity of the technology, the method is used very limited.

Thermal consolidation of soils (roasting) is used mainly for consolidation of subsiding soils. Gaseous, liquid or solid fuels are burned in wells drilled in the ground.

At the same time, air is fed into the well. Firing is carried out at a temperature of 400 ... 800 C for 5 ... 10 days. Around the borehole, a column of fixed soil is formed with a diameter of 1.5 ... 3.0 m with a strength of 1 ... 3 Pa.

Sometimes in practice, the electrothermal method of soil firing is used. Nichrome electric heaters are used as a source. Wells in all cases can be drilled vertically, obliquely and horizontally.

Work on strengthening the bases with the above injection methods must be performed in a specific sequence.

Before performing work on soil consolidation, you should:

- to clarify the location of underground utilities, as well as the location and condition of structures located near the anchorage point;
- to prepare a team of performers who have previously completed a training course in production technology;
- ensure the availability of a set of equipment and materials provided for by the project;
- to carry out control consolidation of the soil and conduct its tests.

The production of soil consolidation includes the following types of work in sequence:

- preparatory and auxiliary work, including the preparation of fixing solutions;
- work on immersion of injectors in soil and drilling, as well as on equipment of injection wells;
- injection of fixing reagents into soils;
- extraction of injectors and sealing of injection wells;
- fastening control works.

Preparatory and auxiliary work is performed before the start of the main work. These include:

- preparation and planning of the territory; supply of electricity, hot and cold water supply, sewerage; establishment (if necessary) of geodetic observation of foundation settlements; placement of chemicals and materials on the site; equipment of a stationary unit for preparing solutions (with a consolidation volume of more than 10 thousand m3 of soil);
- placement of places for immersing injectors or drilling injection wells; coordination of the possibility of carrying out work with electronic supervision and persons responsible for underground communications;

preparation of fixing solutions of working concentrations; control work on soil consolidation.

## 5.2. Principles, organization and technology of work during the strengthening of foundations by deep soil compaction

To increase the strength of the foundations due to soil compaction, mechanical methods are used, the installation of soil piles, the inclusion of rigid elements in the base.

The method of installation of soil piles is based on the immersion of dies that form wells with the displacement of soil radially to the sides. As a result, the soil around the well is compacted. The immersion of the die is carried out by puncture, driving, vibration. Local soil or sand, sand-gravel mixture, crushed stone are poured into the molded well and molded again. The operations are repeated until the average density of the soil mass becomes equal to the required one.

The greatest sealing effect is achieved when the wells are staggered. The distance between the axes of the wells depends on the diameter of the sealing element and the required compaction ratio.

The disadvantage of this method is the presence of vibrations during the plugging, which can cause unacceptable precipitation of buildings.

It should be borne in mind that clayey soils are less responsive to vibration than sands. Long-term exposure to vibration is required to deform clayey soils. Water-saturated sands and sandy loams, which are in a loose state or in a state of medium density, react rather quickly to dynamic influences. Foundations of reconstructed buildings in such soils can be subject to significant uneven settlements due to compaction or squeezing out of the soil from under them.

The danger of vibrations when driving elements that cause settlement of buildings depends significantly not only on the type of soil, but also on the depth of immersion of the shell or pile, the distance from them to existing buildings and a number of other factors. With increasing distance, the displacement amplitudes rapidly decay. This is greatly influenced by soil conditions. The use of lighter hammers leads to a decrease in the amplitudes of ground displacements and their zones of influence.

The amplitude values are maximum when a pipe or pile is driven to a depth of 3 ... 6 m. An increase in the amplitude at a depth can be associated not only with the geological structure of the site, but with discontinuities in the pile driving, for example in thixotropic soils.

In order to reduce the level of vibrations, they reduce the frequency of blows and the height of the hammer fall, increase its weight, and also reduce the "rest" time of the pile during the driving process. The following methods can reduce the level of vibrations: immersion of elements in leader wells, in a thixotropic jacket and indentation.

Deep strengthening of foundations using binders (soil consolidation) is carried out using the following technology. First, a primary borehole with a diameter smaller than a given one is passed through the soil with a spiral projectile, and then the borehole is filled with a fixing material.

After that, along the axis of the primary borehole, a projectile of a larger diameter passes a borehole of the design diameter, pressing the fixing material into the ground. Under the pressure of the submerged projectile, the fixing material penetrates into the soil through the walls of the well and its bottom.

As a hardening mixture, any composition that hardens with soil can be used, for example, chemical reagents used for the chemical consolidation of soils (phenol-formaldehyde, urea and other resins, water glass), as well as cement-sand and cement mortars. To prevent extrusion of the fixing material from the well to the surface, the primary well is filled with the fixing material 1 ... 1.5 m below its mouth, and the diameter of the primary well should be less than 0.8 of the diameter of the planned well.

Depending on the nature of soil strata, consolidation can be performed selectively in individual areas, and the thickness of the layers to be fixed along the length of the well may be different.

At the end of the soil hardening, the wells are filled with soil or other compacted material.

The distance between the wells is determined based on the conditions for ensuring the joint work of the soil in the massif, as well as the necessary bearing capacity of the foundation to be strengthened.

To compact weak water-saturated soils, including watered loess soils, you can use lime-lime piles. In the process of slaking, lime in the well increases in threefold volume. The resulting pressure will significantly strengthen the borehole walls.

Deep compaction can be performed in the form of vertical or inclined wells; a combined well arrangement can also be adopted.

Repair and reinforcement of the body of foundations with polymer-based materials. The method is based on the use of polymer concrete, polymer mortars and mastics for sealing cracks in the body of foundations and injecting them inside. To seal cracks with a width of 2 mm or more and cavities less than 50 mm deep, polymer mortars and polymer mastics are used. If the destruction is more significant and there are outcrops of reinforcement, the restoration is performed with polymer concrete or polymer mortar, application of shotcrete.

In the presence of voids, cracks and other defects inside the body, injection treatment with polymer mixtures of resins with hardeners is used to strengthen it. Due to the high cost of resins, their injection is limited to small volumes of defects.

The device of protective mortar jackets. The method is used to repair minor external damage to foundations. To do this, metal anchors are embedded in the masonry in a checkerboard pattern after 0.5 m, to which a reinforcing mesh is attached, and then a solution is applied on coarse sand by simple plastering or gunning. Sometimes, instead of a solution, concrete is applied using pneumatic spraying or laying in formwork.

# 6. Organization of construction

## 6.1 Construction site planning

Site preparation covers all ancillary installations required to carry out the work specified in the contract. This includes the construction of construction roads on the minefield and their dismantling after the completion of construction works.

The contractor must carry out the construction work under his responsibility, as well as coordinate with the customer and management. At the same time, he must follow the established technological rules and all official instructions. Before starting the work, you must personally draw up a site preparation plan and submit it to management for approval.

It is necessary to follow safety rules and eliminate existing defects immediately.

The contractor must take care of sufficient working and emergency lighting of the construction site.

The contractor is responsible for the installation of drinking and construction water, telephone and electricity systems, as well as the proper disposal of construction water. Development costs and running costs (payroll, consumption costs, etc.) are included in the account.

For the entire duration of the work process it is necessary to take into account the construction office-container in the form of a double container, equipped as a meeting room for 15 people, with appropriate lighting and heating, as well as toilet containers with at least 2 toilets and 4 urinals. The use of the construction site for regular customer meetings is part of the contractor's services.

It is necessary to provide the construction site with a completely closed stationary fence and a blocking gate for the entrance of the required size / width during the entire construction works. Then for the entire duration of the construction work it is necessary to organize a guard service that works 23 hours / 7 days a week / 52 weeks a year. Also for the guard service it is necessary to have a suitable weatherresistant lighted room with heating and toilet for the entire duration of construction work.

The construction area must be provided with open drainage for surface and formation waters, ie all pumping pumps must be in working order.

Incoming surface and formation water must be removed. The costs are borne by the contractor.

For all equipment for the provision and regulation of public transport, including the installation, maintenance and dismantling of road signs, obstacles, warning signs, traffic lights, etc. the contractor answers. The scope of services includes all the necessary side work to ensure the transport system.

The installation of company boards on buildings, fences or on the construction site must be agreed with management.

The contractor is responsible for the installation, maintenance and dismantling of the entire preparatory base.

All external and internal scaffolding necessary for the performance of contractual services must be installed, maintained and dismantled in accordance with the legislation and regulations of the State Inspectorate for Construction Control. They are taken into account in the relevant subcontracting.

It is necessary to carry out a complete cleaning of the construction site every week. More frequent cleaning is possible on request. If transport areas are contaminated during construction, they must be cleaned immediately. Prior to the transfer of the building it is necessary to carry out floor cleaning.

Before starting work, the contractor must provide the licensed surveyor to measure the main angles, all axes in the longitudinal and transverse directions, as well as the reference point of the height network. These measurement results must be taken into account and verified by the contractor during the construction work. All further measurements required for construction shall be performed by the contractor on these principal axes.

The contractor is responsible for installing the foundation for the foundation in front of the pit, including regular inspection and reliable application of measuring notches on each floor.

### 6.2 Earthworks, works on arrangement of sewage and sewerage, cable channels, above-ground works

Access to the construction site is currently via the north-east entrance, which is still under construction. If the municipality plans to build a road in Pidhirtsi from the southern part of the site, then the entrance will be built on this street, and the previous entrance will be dismantled.

When installing outdoor structures, both access options must be considered. Due to this, the structural and technical expansion of the automatic sliding gate with a length of 13 m in the form of a double gate with a second smaller sliding gate is provided. It is also planned to install a barrier (not double 2 x 4 m) 1 x 8 m or a double barrier 2 x 8 m for future entry. Thus, these building elements can later be placed and expanded elsewhere.

In addition, the checkpoint must be located so that it is compatible for both entrances.

It should be noted that the access roads and detours of the site must be provided by 5-axle saddle trains and articulated trains in one-way traffic, but in special cases, the production area for the supply of special or heavy equipment on the road can go 12-axis trains 34 m long.

The detour for special transport is not planned - they will be sent to the south-western warehouse. Appropriate paths and axial loads are provided by the customer and must be recorded in the working drawings of the entrances and the industrial area.

Parking spaces for employees and customers are located in such a way that uncontrolled access to the industrial area is impossible. In addition, employees can only park outside the industrial area.

Execution of works is subject to general official regulations, special regulations and instructions of the inspection of construction control and competent supply and disposal enterprises, relevant norms, laws and other norms, trade union and traffic regulations. Contradictions must be resolved in a timely manner with senior construction management.

All prepared work, regardless of the type, which must be carried out to accept and start work, is carried out by the contractor. Complications, regardless of the type and whether the contractor is responsible for them or not, do not prolong the construction time and do not cause the need for compensation.

The contractor must take care to reach the construction site by any means of transport. Obstacles do not affect the completion date, do not extend the construction time and do not cause the need for compensation.

The backfill soil must be carefully compacted. The cost of quality assurance due to engineering and geological examination or the like, which arise during the installation is the business of the contractor.

All excavation operations must take into account the qualification stabilization of the soil with binders (lime, cement or lime-cement mixture).

Appropriate additional costs for the soil stabilized by the hardened binders during excavation must be taken into account. Due to the fact that the binders for soil stabilization are frozen, the selected soil on the site must be stored for further processing (cutters, mortars), and the pits for the foundation are technically filled with foreign materials and compacted.

Interrupted communication lines must be stabilized with a suitable binder and compacted technically correctly after backfilling on the project surface of the ground at a milling depth of 0.40 m; this operation is included in the construction cost.

For sketch design in the area of external structures of the general scheme, 70 cm from the upper edge of the project surface of the subsoil (52 cm of filtering and frost protection layer of gravel, 14 cm of bearing layer and 4 cm of surface layer) were allocated.

For sketch design in the area of the axis A-E / 4-12 of the General scheme was allocated 50 cm from the upper edge of the design surface of the ground. At the same time, 30 cm of frost protection layer of gravel and 20 cm of foundation slab of concrete are planned.

It is necessary to lay the entire construction site for the passage of heavy vehicles of class SLW 60 according to DIN 1072. According to DIN 1072, the concept of SLW 60 corresponds to a truck 3 m wide and 6 m long with a total load of 600 kN (60 t), divided into 3 axes s indentation 1.50 m, axle load 200 kN (20 t), wheel load 100 kN (10 t) and tire bearing surface 0.2 x 0.6 m.

All duct systems, plastic pipes, local control shafts, cable shafts, back-up storages and tanks, foundation slabs in the adjacent area, etc. must be laid and installed at the required depth accordingly.

It is necessary to take into account and check the suitability of the materials used in relation to these loads. Thus, for all pipes, mines, tanks and other containers laid in the ground, it is necessary to indicate the load and depth check in the soil and present it before starting work. All protective floors such as hatches, gutters, etc. must be installed in class D 400 in accordance with DIN EN 1433.

The regulation of traffic and transport safety at the construction site also includes roads and ancillary facilities that are under traffic and are taken into account by the contractor during the works. Documentation of the actual condition of the roads is performed by the contractor, otherwise the road administration will file claims for compensation. Contaminated streets are subject to constant cleaning.

Littering by the owner of the adjacent plot must be visually minimally marked.

Only sites are provided by the customer for site preparation, equipment placement, etc.

All plots must be returned to their original condition without any payments after the completion of construction works.

Under no circumstances should adjacent private plots be used without the owner's permission.

All places where there is equipment, workplaces, etc. must be surrounded by stable high fences about 2 m high, and close them during non-working hours.

### 6.3 Organizational and technical preparation for construction

General organizational and technical preparation for construction must be performed in accordance with the rules of contracts.

This requires:

• provide construction with design and estimate documentation;

• draw up a contract;

• establish subcontractors, suppliers of equipment, materials and structures;

• establish the sequence and executors of works;

• fence off the construction site, provide it with transport and fire passages; provide electricity and water supply networks;

• perform installation of inventory structures, prepare warehouses and storage area;

• provide construction with communication facilities and fire alarms;

• timely provide construction with the necessary construction machines and mechanisms.

### 6.4 Water and electric energy consumption calculation

The calculation of the need for construction in energy and water is performed in accordance with the calculation method Annex 2 "Manual for the development of projects for the organization of construction and projects for the implementation of works" to DBN.

The total electricity demand for the construction site is determined by the formula:

$P=1,1/(\text{"cos"}\ \phi)(K1\Sigma P1+ K2\Sigma P2+ K3\Sigma P3+ K4\Sigma P4)$,

P - total power demand kW;

1.1 - factor that takes into account power consumption in networks;

K1, K2, K3, K4, - coefficient of simultaneity, depending on the type and number of consumers;

P1 - power consumed by construction machinery, tools, mechanisms

P2 - power consumption for technological needs - 0 kW;

P3 - power consumption for interior lighting:

- office and domestic premises - 1 × 5.4 × 0.015 kW = 0.081 kW

- storage facilities - 16 × 0.003 = 0.048 kW

P3 = 0.081 + 0.048 = 0.13 kW

P4 - power consumption for outdoor lighting:

- work performance areas - 100 × 0.0008 = 0.08 kW

- main passages and passages - 200 × 0.005 = 1 kW

- secondary passages and passages - 0 × 0,0025 = 0 kW.

P4 = 0.08 + 1 + 0 = 1.08 kW

Total P3 = 0.13 kW, P4 = 1.08 kW

cos ϕ = 0.75

K1 ÷ K4 - simultaneous coefficients:

Thus, the total electricity demand for the construction site is:

P= "1,1" /"0,75" (0,6·37+1,0·0+1,0·0,13+1,0·1,08)=34".3" кW

Power supply of the construction site is provided from the existing electrical panel, which is located on the territory of LLC.

The use of water to meet production needs is virtually non-existent. Concrete and mortar are delivered to the site ready, and finishing work is performed with a minimum number of wet processes.

Water consumption for household needs is determined by the formula

$$Q_2 = K_2 \frac{q_2 \cdot n \cdot K_2}{t_1 \cdot 3600} + \frac{q_2 1 \, n_2 1}{60 \cdot t_n}$$

It is accepted for calculation

q2 - specific water consumption for household needs - 25l / shift;

n2 - the number of employees in the busiest shift - 7x0.6 = 4 people;

$K_2$ - coefficient of uneven water consumption - 1.5;

$Q_{21}$ - water consumption for showering by one employee - 30 liters;

$N_{21}$ - the number of workers who use the shower - 4x0.4 = 2 people;

t2 - the duration of the shower - 45 minutes

t1 - working time of consumers - 8 hours.

$Q_2 = 1,5\ \frac{25 \cdot 4 \cdot 1,5}{8 \cdot 3600} + \frac{30 \cdot 2}{60 \cdot 45} = 1,5\ (0,0052+0,022) = 0,041$ l/sec

According to table 6 of the "Manual for the development of construction projects" indicator of water consumption for firefighting needs with a building volume of 2439.2 m3 and IIIa degree of fire resistance and is Q = 10.0 l / sec.

The total water consumption to meet the needs of construction is Qobshch. = 0 + 0,041 + 10 = 10,04 l / sec

Provision of the construction site with drinking water is carried out by means of imported water "bottled".

Consumers of compressed air are pneumatic rammers and painting machines.

- pneumatic rammers 2 pcs. x 0.8 = 1.6 m3 / min.

- painting machines of 1 piece. x 0.25 = 0.25 m3 / min.

The power of the compressor unit is determined by the formula:

$N = m\Sigma qKo = 1.4 \times (1.6 + 0.25) \times 0.9 = 2.33$ m3 / min

To ensure the construction of compressed air is accepted mobile compressor station PKS -5 with a capacity of 5m3 / min

## 7. Safety protection and labour precaution

### 7.1 Main considerations

For exclusion or reduction of influence of dangerous physical factors and creation of safe conditions at maintenance and repair of the technological and hoisting-and-transport equipment the project provides for the following actions:

- Maintenance of cars and mechanisms from platforms, which are protected by a handrail;
- Protective fencing of mobile parts of the equipment;
- Thermal protection of devices and pipelines, the surface of which can heat up above 40oC;
- Equipping of pressurized devices with precautionary valves;
- Use of corresponding load-lifting cranes and mechanisms for moving and lifting of cargoes for repair of the equipment;
- Blocking of unauthorized access to electric control panels and boards of automatic;
- Signal-alarm coloring of building structures and industrial equipment, pipelines and intrashop transport representing danger of failures and accidents;
- Placing in premises and in territory of the enterprise of safety signs according to GOST 12.4.026-76;
- Use of the lifting equipment according to the requirements of НПАОП 0.00-1.01-07 (ДНАОП 0.00-1.03-02) and НПАОП  0.00-1.36-03.

According to GOST 12.2.022-80 ССБТ. Conveyors. General safety requirements, the project provides for the following:

- Protective fencing of conveyors in places of possible access of people to them;
- Equipping of conveyors with emergency stopping devices allowing to stop the conveyor from any place;
- Sonic and light warning about start-up of conveyors;
- Corresponding safe distances of conveyors from building structures.

For reduction of negative influence of noise from the technological and ventilating equipment on the working personnel the project provides for the following:

- Installation of process equipment with increased noise level (scalpel tool, separators, crushers, etc.) in separate premises (buildings, constructions);
- Installation of aspirating and circulating fans in separate premises (portable platforms) with sound insulation so that the noise level in industrial premises did not exceed 80 dBA;
- Use of individual protection means (bushes, ear-phones etc.);
- Remote control of mechanisms and equipment.

At permanent workplaces in industrial premises, the noise level does not exceed 80 dBA.

For reduction of adverse influence of vibration from the technological and ventilating equipment on the personnel, the project provides for installation of crushers (grinders, separators) and fans on vibration insulating platforms and load-bearing structures not connected to the maintenance platforms.

Sources of ultrasound, infrasound, electromagnetic and ionizing radiation at the enterprise are unavailable.

***Adverse microclimatic factors and design solutions for labor protection***

Adverse microclimatic conditions, first of all, can occur upon working in unheated premises and in enterprise territory during the cold season. Such places include:

- seeds intake with flat store;
- Grain preparation complex for storage and processing;
- Extraction plant;
- Pellet loading platforms oil warehouse with the loading terminal.

For prevention of colds and eventual overcooling of employees, on the workplaces of which the microclimatic conditions are below admissible sizes (loading platforms, extraction plant, scales, etc.) during the cold season, in connection with technical and economic inexpediency of the artificial heating device there are provided, according to item 2.14 of ДСН 3.3.6.042-99, the corresponding design actions - premises for heating and warm clothes, placed in building 3 (control room with a lab), 5 (intake lab), 21 (technical office with a warehouse and workshop), 27 (garage) etc.

The personnel working outdoors during the cold season is provided with additional warm clothes and footwear, and the intra-shift operating mode provides for possibility of breaks for warming up.

**Labor safety provision in the operation process**

For the purpose of creation of safe working conditions, improvement of the training quality on site, the administration should organize training and examination on labor safety for the personnel engaged in works with increased danger, for performance of which special training and annual examination on labor safety is required.

Technological process should be carried out according to the production schedules approved according to the established procedure (TP), in which there should be Labor Safety sections and the list of obligatory instructions should be given.

In accordance with TP at the enterprise there should be instructions on maintenance, repair, labor safety and fire safety approved according to the established procedure taking into account specific features of technology, technical requirements of the equipment operation and properties of the used raw and other materials.

The basic documents which the maintenance should follow are as follows:

- Production schedules;
- Executive working documentation;
- Engineering specifications for manufactured products;
- Engineering specifications for raw and other materials, which are used in

production;

- Technical reports of the commissioning organizations;
- Instructions on a labor and fire safety;
- Job descriptions;
- Approved schedule of scheduled preventive maintenance of the equipment;
- Log of periodic surveys and repair of the equipment and constructions;
- Plan of localization and liquidation of emergencies and failures;
- Technical operational documentation for equipment.

In the course of operation it is not allowed to:

- Overload of the equipment above passport and design norms;

- Infringe the maintenance terms and scheduled preventive (current and capital) equipment repairs;

- Infringe the equipment technical operation rules, safety precautions regulations and fire safety by maintenance staff;

- Infringe the requirements of technological documentation.

Putting of the industrial equipment in operation should be carried out after obligatory tests and registration of acceptance certificates.

Operation of the lifting equipment should be carried out according to the requirements of НПАОП 0.00-1.01-07 (ДНАОП  0.00-1.03-02) and НПАОП 0.00-1.36-03.

**Monitoring of compliance with safety requirements**

Monitoring of compliance with safety requirements is carried out at the enterprise according to the applicable legislation of Ukraine and applicable statutory acts on labor safety.

The owner of the enterprise should permanently control the observance of technological processes, rules of dealing with cars, mechanisms, equipment and other means of production, use of means collective and individual protection, and performance of works according to labor safety requirements by employees.

The trade union controls observance of legislative and other statutory acts on labor safety, creation of the safe and harmless working conditions, appropriate industrial life for workers and provision them with collective and individual protection means by the owner.

The trade union has the right to verify the conditions and safety of work on production site, performance of corresponding programs and collective agreement obligations, to bring proposals on labor safety to the owner, to state management structures and to receive the substantiated answer from them.

The state supervision of compliance with legislative and other statutory acts on labor safety is carry out by:

- Local bodies of the State committee of Ukraine for labor safety supervision;
- Local bodies of the state fire supervision of the administration for fire protection of the Emergency Management Ministry of Ukraine;
- Local bodies and establishments of sanitary-and-epidemiologic service of the Health Ministry of Ukraine.

The beginning of construction (reconstruction) of the enterprise, implementation of new technologies and means of production is possible only after examination (check) of the design documentation as of its conformity with statutory acts about a labor safety, fire safety and state sanitary-and-epidemiologic examination. Financing of these works can be conducted only after obtaining of positive results of examination.

For putting in operation of the new (reconstructed) objects of industrial appointment, manufacturing (installation, installation) and transfer of samples of new cars, mechanisms, equipment and other production means in operation, implementation of new technologies it is necessary to obtain the permit of bodies of the state supervision of a labor safety and state structures of the fire and sanitary inspection.

Acceptance in operation of the enterprise ready for production is carried out according to the Order of Gosstroy of Ukraine dated 10/18/2004 №191 About the order of acceptance of completed construction objects in operation.

In the course of performance of commissioning works and periodically at the enterprise operation it is necessary to control the keeping of harmful substances and dust content on constant workplaces and in enterprise territory as of compliance with requirements of GOST 12.1.005-88, Specifications of the maximum admissible emissions of pollutants from stationary sources and ДСП-201-97 State sanitary rules of the atmospheric air protection in settlements (from pollution with chemicals and biological substances) and, if necessary, to develop the corresponding solutions (repair and adjustment of ventilating systems, replacement of the worn out units of equipment, restoration of hermetic sealing of the equipment etc.). The laboratory accredited according to the established procedure should provide the control.

The project provides for automatic control of the air environment of corresponding industrial premises (buildings, constructions) behind the solvent maintenance (pre-explosion hazardous concentration).

In the course of the commissioning works and at enterprise operation it is necessary to control the noise levels on constant workplaces and in enterprise territory from time to time according to ДСН 3.3.6.037-99 and, if necessary, to take the corresponding steps (replacement of the worn out units of equipment, restoration noise-protective coverings etc.).

Control of operation of the hoisting-and-transport equipment should be carried out according to НПАОП 0.00-5.20-94 (ДНАОП 0.00-5.20-94) Typical instruction for maintenance staff controlling the maintenance and safe operation of the lifting cranes and НПАОП 0.00-1.36-03 by the official from among ITR, appointed by order for the enterprise.

After completion of installation, adjustment, running in or after major repairs, updating and reconstruction of conveyors the control of compliance with safety requirements should be performed in accordance with GOST 12.2.022-80.

**Labor safety provision upon refrigerating machinery operation**

Upon operation of refrigerating machinery and installations the following dangerous and harmful production factors can be available:

1. Physical: mobile parts of compressors, increased noise, vibration, high pressure of freon in the system; danger of electric shock.

2. Chemical: irritating influence on skin and mucous membranes of eyes, nose and throat of freon steams and used lubricants; suffocating action of freon on the person upon accident.

If liquid freon is applied to skin, it is getting frostbitten.

For reduction of influences of harmful production factors, the project provides for the following actions:

1. The enterprise administration is obliged to provide the refrigerating machinery with necessary maintenance staff.

2. The persons elder than 18, who passed physical examination and have the certificate on the completion of special educational institution or courses on operation of the refrigerating machinery are allowed to maintain the refrigerating machinery.

3. Operation of the refrigerating machinery should be performed according to the instruction developed by the enterprise administration on the basis of Rules of Construction and safe operation of refrigerating machinery, manufacturer's instruction and other regulations concerning safety precautions.

At refrigerator installation sites, the following instructions should be hung out in a prominent place:

- On the composition and safe operation of the refrigerating machinery;
- On maintenance of machinery and devices;
- On personnel actions at emergency occurrence;
- On fire safety;
- On rendering of the pre-medical assistance;
- On labor safety;

Refrigerator installation sites should be provided with primary fire extinguishing means (for E category site).

4. Access of unauthorized persons to refrigerators installation sites is forbidden.

5. At refrigerator installation sites, the storage of kerosene, gasoline and other inflammable liquids is forbidden.

6. Transportation and storage of freon should correspond to the requirements of regulations and industrial instructions. Freon should be stored in cylinders designed for it with max capacity 40 liters or in containers with max capacity 1 ton, having distinctive coloring and inscription.

7. At refrigerator installation sites the special places for storage in the closed kind wiping rubbing cloth, tool, linings, etc., and for storage of a week stock of oil should be provided.

8. The platforms under refrigerators and compressor blocks should be separated from the platforms of walls or building columns. Upon installation of refrigerating units on the façade it is necessary to provide the solutions reducing the possibility of vibration transfer on building structures.

9. At refrigerator installation sites, it is necessary to provide the working and emergency illumination.

10. All moving parts of machinery as well as machinery, devices and pipelines in places where they can be exposed to blows, should be protected. Cases of compressors should be earthed.

11. The refrigerating machinery should be provided with devices of automatic protection and regulation. The compressors should be equipped with protective temperature relays stopping them at excess of 170°C by the forcing temperature for R407C.

# 8. ENVIRONMENT PROTECTION

## 8.1. Water Reservoirs protection

The household sewage provides for collection and withdrawal of drain waters from sanitary devices and shower cabins into external networks of the household sewage, and further, into designed KNS-1 with subsequent swapping of drains into the existing sewer collector withdrawing the household drain waters to treatment facilities for biological cleaning in Lyubashovka town with output 500 m3/day.

The discharge of household drain waters arriving to KNS-1 is 19.20 m3/day.

Industrial drain waters from the boiler-house in the amount of 156.29 m3/day are withdrawn by self-flowing pipelines into KNS-2 and further are pumped over to the treatment facilities in Lyubashovka town for their dilution with cleaned sewer drain waters.

The system of the rainwater drain provides for collection and withdrawal of rain water from the enterprise territory into a ditch located 2.0 km away from the enterprise.

The general discharge of the rain drains is 398.0 l/s. The estimated discharge of rain sewage is defined according to Recommendations on design of constructions for cleaning of superficial drain from territories of the industrial enterprises.

The most polluted part of the rain drains with discharge of 92.0 l/s is withdrawn through a well with an adjustable spillway, in chambers of treatment facilities where it is cleaned according to sedimentation and filtration method. As treatment facilities the separators of oil products for sewage treatment OLEOPATOR K NS 100 by AKO Building Elements Ltd. are accepted, with output 30.0 l/s.

Cleaning effect:

- by weighed substances – 99.0 %;
- by oil products – 99.3 %.

After cleaning, the cleaned waters are collected in the tank-store of the cleaned rainwaters with capacity of 500 m3 and are used for watering of territory and green plants.

The deposit formed in the course of cleaning and referred to the 3rd class of safety is taken out for recycling.

The deposit formed in the course of cleaning and referred to the 4th class of safety is taken out by cesspool emptier and can be used in municipal services.

## 8.2. Air Protection from Pollution

Solutions for protection of atmospheric air from pollution with emissions of harmful substances are presented in Environmental Influence Assessment section.

Results of calculation show that the expected concentrations of polluting substances below maximum concentration limit of these substances for the settlements.

***Sanitary-protective zone***

According to the State sanitary rules of settlements design and development, approved by the Environment Protection Ministry on June 19, 1996 No. 173, the enterprise is referred to the 4th class of safety with the 100m a sanitary-protective zone.

## 8.3. In-Plant Noise Reduction

For reduction of sound pressure at fixed workplaces, the project provides for the following solutions:

a) Equipping of gas and cold supply systems: installation of the compressor equipment in a soundproofing casing, installation of the equipment with dynamic loadings on vibration insulation platform;

b) Equipping of heating and ventilation systems: installation of ventilation units on spring vibration insulation platforms, distribution of air ducts basically in back offices, connection of fans to air ducts through soft inserts, placing of ventilation units in the premises isolated from the rest of the site.

Solutions for reduction of in-plant noise are presented in Environmental Influence Assessment section.

Calculations of level of sound pressure from the technological and ventilating equipment nearby the nearest apartment house show absence of excessive of sound pressure over standard indicators in the territory directly adjoining the apartment houses according to.

The supply-and-exhaust ventilation systems are designed with noise-killers. Fans are installed on vibration insulating foundations.

The ventilating equipment is connected to air ducts through soft inserts.

At noisy workplaces the employees use personal earplugs.

### 8.4. Energy-Saving Measures

***Administrative office***

Upon design of walls of the administrative office with use of thermally heterogeneous filler structures (ordinary clay brick, extruded expanded polystyrene, obverse brick), the thermal insulating material is applied from outer side of load-bearing walls and protected with obverse brick.

The plinth and floors on soil are warmed with thermal insulating plate materials 0.5 m deep below the ground surface.

Intervals in places of adjunction of window and door cases to the external wall structures are filled with foaming synthetic materials.

The heating devices shall be placed under window apertures with installation of heat-reflecting insulation between devices and external wall.

***Industrial buildings***

Upon design of industrial buildings using the multilayered metal structures and thermal insulating mineral wool insulating plates for reduction of thermal heterogeneity, in the facade plane there is provided dense engagement of thermal insulating materials to columns, beams, profiles, internal partitions, and ventilating channels. Through inclusions (cores, bolts) should be isolated with thermal insulating materials. The plinth is warmed with thermal insulating plate materials 0.5 m deep below the ground surface.

The span life of the used thermal insulating materials should be min 25 years, replaceable sealants – min 15 years with provision of reparability of thermal insulating cover elements.

After estimated span life of thermal insulating materials the check of thermal insulating capacities of the filler structures with the further development of constructive solutions for provision of necessary thermal insulating capacities of the building cover is necessary.

In the pressing plant, the P2-P10 systems are designed with recuperators with glycol tubes. It allows saving heat for heating of input air in input systems by 70 %.

In the pelleting plant, the P1-P2 systems are designed with recuperators with glycol tubes. It allows saving heat for heating of input air in input systems by 75 %.

In the administrative office the conditioner, K1 system, is designed with a cross recuperator. It allows saving heat for heating input air in the conditioner by 30 %.

# 9. Scientific-Research part

## 9.1 Introduction

Steel-concrete composite beam with profiled steel sheet has gained its popularity in the last two decades. Due to the ageing of these structures, retrofitting in terms of flexural strength is necessary to ensure that the aged structures can carry the increased traffic load throughout their design life. The steel ribs, which presented in the profiled steel deck, limit the use of shear connectors.

This leads to a poor degree of composite action between the concrete slab and steel beam compared to the solid slab situation.

As a result, the shear connectors that connects the slab and beam will be subjected to higher shear stress which may also require strengthening to increase the load carrying capacity of an existing composite structure.

While most of the available studies focus on the strengthening of longitudinal shear and flexural strength separately, the present work investigates the effect of both flexural and longitudinal shear strengthening of steel-concrete composite beam with composite slab in terms of failure modes, ultimate load carrying capacity, ductility, end-slip, strain profile and interface differential strain.

The flexural strengthening was conducted using carbon fibre reinforced polymer (CFRP) or steel plate on the soffit of the steel I-beam, while longitudinal shear capacity was enhanced using post-installed high strength bolts.

Moreover, a combination of both the longitudinal shear and flexural strengthening techniques was also implemented (hybrid strengthening).

It is concluded that hybrid strengthening improved the ultimate load carrying capacity and reduce slip and interface differential strain that lead to improved composite action. However, hybrid strengthening resulted in brittle failure mode that decreased ductility of the beam.

Steel-concrete composite structures are widely adopted in the construction industry for the construction of building, bridges, etc. In recent years, steel-concrete composite beam with composite slab (concrete slab with profiled steel sheet) has gained attention in terms of research and construction. Due to the ageing of existing structures and to meet the increasing demand to carry additional load, a number of steel-concrete composite structures require external strengthening.

However, research on retrofitting of steelconcrete composite beams with profiled sheet is still limited in the literature. Most of the available works that focus on the retrofitting of steel-concrete composite beams are related to the solid concrete slab (without profiled sheet).

Retrofitting of these composite beams are achieved by strengthening the steel Ibeam using steel plate or carbon fibre reinforced polymer (CFRP). To repair a composite beam member, the effect of CFRP layer/thickness on the flexural strength of the composite beams are investigated.

While the above studies strengthened the steel flange only to improve the structural properties of the composite beam, strengthening other components of the composite girders are also reported in some literature.

Al-Saidy et al. strengthened both the steel web and flange separately and combined to increase the flexural strength of a composite beam. Sallam et al. (2005) suggested the application of steel plate welded and/or bonded to the compression flange of the steel girder as well.

In addition, another study of the same authors compared three different strengthening technique that included the application of CFRP plate on the tension flange only, CFRP plates on tension flange and steel plate on the compression flange and steel plates on both flanges.

The conclusions of this study include, CFRP sheet is more effective than CFRP plates (one layer) in terms of improvement in ultimate load and bonded or welded steel plates performed better for load transfer.

Similar conclusion was reported using pre-stressed CFRP sheets in studied the effect of the compressive strength of concrete, the cross-sectional area of the bottom flange of the steel beam and the stiffness, thickness and ultimate strain of the CFRP on the flexural strength of composite beams.

It can be noted that the aforementioned studies on the retrofitting of steel-concrete composite beam with solid slabs focused primarily on the flexural strengthening of the beam.

Even though slip exist at the interface of a steelconcrete composite beam with a solid slab at a very small load as well (Johnson 2008, Saravanan et al. 2012), this effect is more prominent in steel-concrete composite beams with profiled sheet due to the limited number of shear connectors which can be placed within the rib of the profiled sheet. The effect of slip due to the limited number of shear connectors in a profiled sheet contained composite slabs were also reported in (Nie et al. 2005, Nie et al. 2008).

Moreover, the shear capacity of the connectors in the profiled steel sheet is lower compared to the solid slab because of the local failure of the concrete rib (EN 1994; Construction 2000). Accordingly, enhancement in longitudinal shear capacity of a composite beam with profiled steel sheeting require attention while rehabilitation of this type of structural system is the point of interest.

Friedrich et al. (2017) reported the use of a novel steel sheet which enhance both the longitudinal shear and flexural capacity of the composite slab. The slip behaviour of blind bolt and welded stud connectors in grout in rehabilitated steel-concrete composite beams were explore in (Pathirana et al. 2016, Pathirana et al. 2016, Henderson et al. 2017).

In addition to the longitudinal shear failure, flexural and vertical shear failure are also common in composite beam with composite slab (Gholamhoseini et al. 2014). Therefore, retrofitting of composite beam with composite slab perhaps require the strengthening of more than the flexural enhancement only. Consequently, in order to strengthen the longitudinal shear between steel beam and concrete slab in composite system with profiled sheeting,

Pathirana et al. (2015) proposed the use of two special types of post-installable bolted connections and welded headed stud connector.

Kwon et al. (2010) also suggested the implementation of post-installable bolts to rehabilitate noncomposite bridges. Demir et al. (2018) also proposed the implementation of external steel member to enhance both flexural and shear capacities of conventional reinforced concrete members. The present study focuses on the retrofitting of steelconcrete composite beam with profiled sheet in terms of both the longitudinal shear and flexural strength.

The flexural strength is enhanced by using CFRP and steel plate on the soffit of the steel I-beam, while additional shear studs are installed in the concrete slab to increase the degree of shear connection. Since space is limited in the rib of the profiled sheet and above the steel top flange, the postinstalled studs are placed further away from the top flange of the I-beam, but connected to the top flange using a steel plate, as shown in Fig. 1. The CFRP is attached to the steel beam using epoxy, whereas steel plate is welded on the bottom of the steel I-beam.

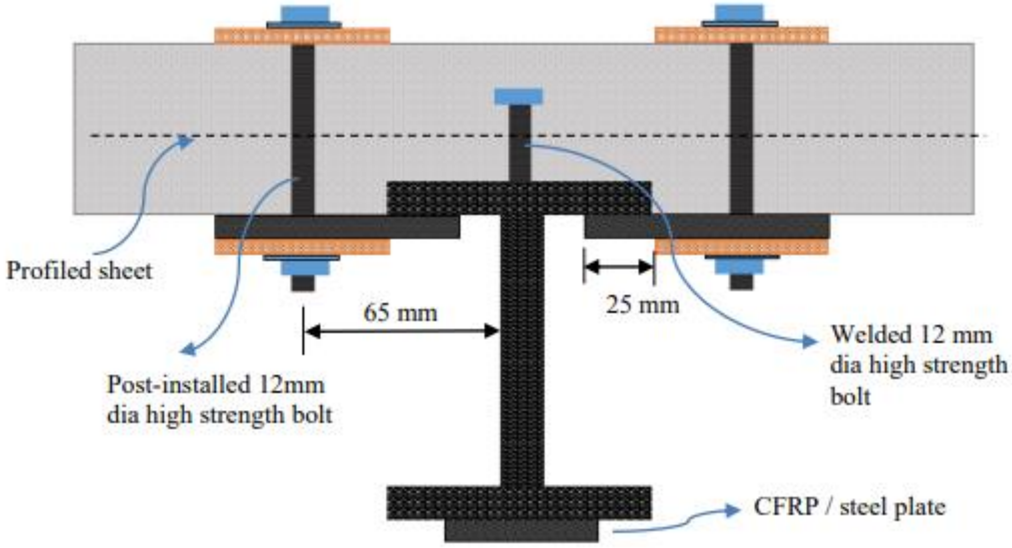


Fig. 1 Flexural and longitudinal shear strengthening of steel-concrete composite beam with profiled sheet

Composite construction consists of providing monolithic action between prefabricated units like steel beams or pre-cast reinforced concrete or pre-stressed concrete beams and cast-in-situ concrete, so that the two will act as one unit. Although there is bound to be a certain amount of natural bond between concrete and steel at least at the initial stages, this bond cannot be relied upon as the same is likely to be deteriorate due to use and over load.

Mechanical shear connectors are therefore provided to help the steel and concrete element to act in a composite manner ignoring the contribution made by the inherent natural bond towards this effect. Primarily shear connectors are intended to resist the horizontal movement between the concrete slab and the steel beam and to transmit the horizontal shear between the two. Shear Connectors are also called upon to prevent vertical separation of the slab from the steel girder at the contact surface.

Therefore, shear connectors are to be designed to cater for integral action of the composite structure at all load conditions on the following basis:

a) Transmission of longitudinal shear along the contact surface without slip.

b) Prevention of vertical separation of the in-situ RC slab from the pre-fabricated structural beam.

**Types of Shear Connectors**

Shear connectors are generally classified into three categories, viz.

a) Rigid type

b) Flexible type

c) Bond type The basic characteristic of the above connectors are discussed below: (a) Rigid Type Connectors: These connectors as the name implies, are designed to be bent proof with little inherent power of deformation. These types of shear connectors could be of various shapes, but the most common types are short length of bars, angles or tees welded on to the steel girder in manners shown in Figure 1. These connectors derive their resistance from bearing pressure of the concrete, distributed evenly over the surface because of the stiffness of the connectors.

Failures in these types of connectors are generally associated with the crushing of concrete. It is customary to provide suitable anchorage device to these connectors to prevent in-situ concrete from being separated from the structural unit in the direction normal to the contact surface.

The common method for this is to introduce longitudinal round bars through holes provided in the rigid connectors (Figure 1).

**Flexible Type Connectors**:

Flexible type connectors such as studs, channels welded to the structural beams derive their resistance essentially through the bending of the connectors and normally failure occurs when the yield stress in the connector is exceeded resulting in slip between the structural beam and the concrete slab.

Typical types of flexible connectors are illustrated in Figure 2. c) Bond or Anchorage Type Connectors: These connectors derive their resistance through bond and/or anchorage action. Typical bond type connectors have been illustrated in Figure 3. These normally consist of the following: Inclined bars with one end welded to the flange of the steel unit and the other suitably bent. M.S. bar welded to the flange of the steel unit in the form of helical stirrups.

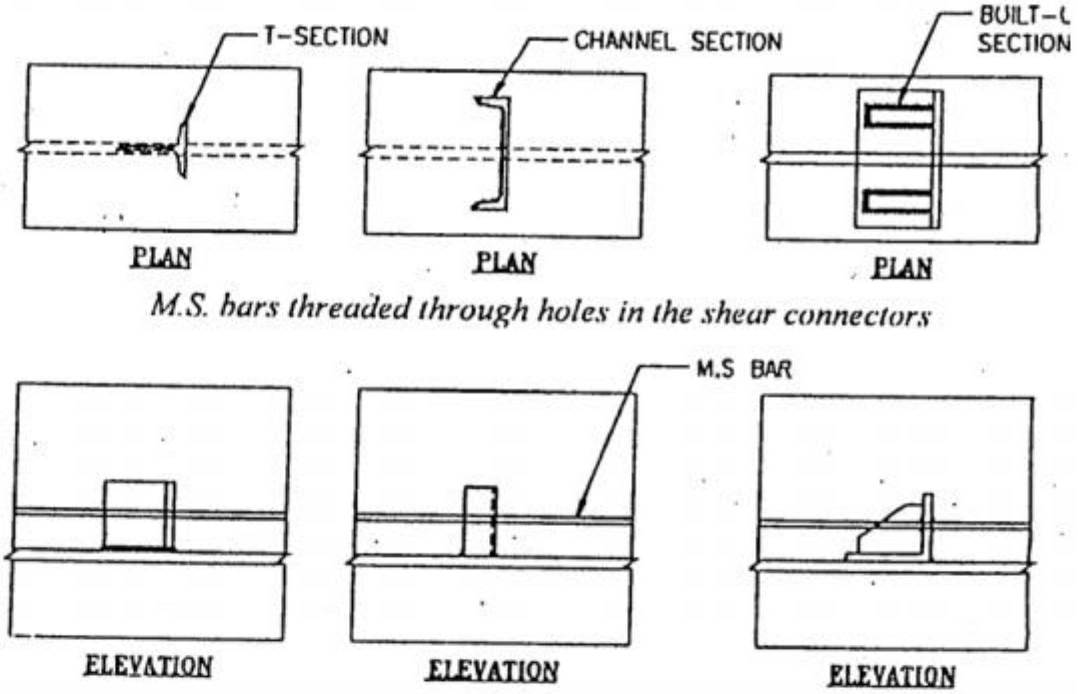


*Fig. 1 . Typical rigid connectors with anchorage device to hold down the concrete slab against uplift*

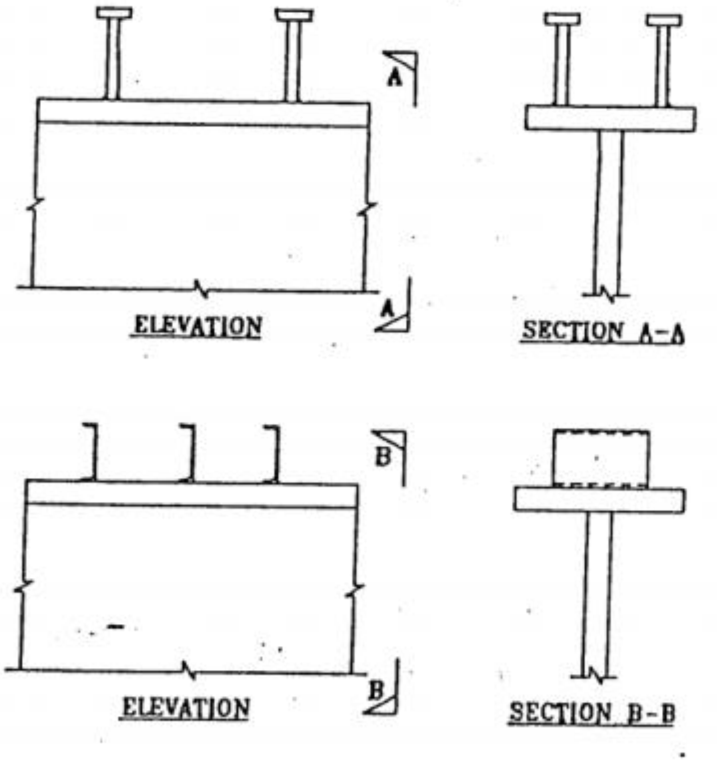


*Fig. 2 Typical flexible connectors*

**Design Strength of Shear Connectors:**

Relevant codes: In India, primarily two codes of practices are in use for composite construction in structural steel and concrete.

These are: Standard specifications and code of practice for road bridges, Code of practice for composite construction in structural steel and concrete, It is proposed to discuss in the following paragraphs the methods recommended by these codes for calculating design strength of shear connectors:

Shear Connectors as per IRC:22-1986 Shear connectors may be either mild steel or high tensile steel according to the material specification of the steel beam. As mild steel beams are commonly used as construction material in India, design methodology of mild steel shear connectors is being discussed in the following sections.

Shear capacity Shear capacity of a shear connector may be calculated as follows:

(a) For welded channel/angle/tee connector made of mild steel with minimum ultimate strength of 420 to 500 MPa, yield point of 230 MPa and elongation 21%.

$$Q = 3.32\left(h + 0.5t\right)Lf_{ck}$$

Where,

Q = The safe shear resistance in Newton of one shear connector

h = The maximum thickness of flange measured at the web in mm

t = Thickness of the web of shear connector in mm

fck = Characteristics compressive strength of concrete

**Longitudinal shear force**

In a composite beam, the longitudinal shear force to be transmitted by the shear connectors is given by the formula:

$$V_1 = \frac{VA_cY}{I}$$

Where,

V1 = The longitudinal shear per unit length at the interface in the section under consideration

V = The vertical shear due to dead load and live load including impact acting on the composite section.

Ac = The transformed compressive area of concrete above the neutral axis of the composite Section.

Y = The distance of the neutral axis of the composite section to the centroid of the area under consideration.

I = The moment of inertia of the whole transformed composite section.

b) When the deck slab is cast with the girder un-propped, the shear V will be the total external shear due to load added after the concrete has attained a strength compatible to the composite action assumed plus the live load with impact.

c) In case (b), when the slab is supported independent of the girder system, the shear will be the total external shear including the self-weight of the slab.

Spacing of shear connectors

1) Shear connectors are to be provided throughout the length of the beam and may be uniformly spaced between critical cross sections.

2) Spacing of the shear connectors shall be determined from the formula

$$p = \sum \frac{Q}{V_1}$$

Where,

p = Pitch of shear connectors

V1 = The longitudinal shear per unit length at the interface in the section under consideration

Q = Safe shear resistance of each shear connector as computed in earlier section.

∑Q = The total shear resistance of all connectors at one transverse cross section of the girder

3) The maximum spacing of the shear connectors in the longitudinal direction shall be limited to:

(a) 600 mm or

(b) thee times the thickness of the slab or

(c) four times the height of the connector

Whichever is the least.

4) The spacing of the stud connectors in any direction shall not be less than 75 mm.

Detailing

a) Dimensions of haunches

The dimensions for the haunches to be provided between top of the stud and soffit of slab shall be as indicated in Figure 4, the sides of the haunches being located outside at the line drawn at 45 degrees from the outside edge of the base of the connector.

**Dimensions of shear connectors.**

1) The diameter of the stud connectors welded to the flange plate shall not exceed

twice the plate thickness

2) The height of the stud connectors shall not be less than four times their diameter or 100 mm

3) The diameter of the head of the stud shall not be less than one and a half times the diameter of the stud.

4) The leg length of the weld joining other types of connectors to the flange plate shall not exceed half the thickness of the flange plate.

5) Channel and angle connectors shall have at least 6 mm fillet welds placed along the head and toe of the channels/angles.

6) The clear distance between the edge of the girder flange and the edge of the shear connectors shall not be less than 25 mm.

7) The surface of the shear connector which resists the separation between the units (ie. The under side of the stud or the inner face of the top flange of a channel or

the inside of a hoop shall extend not less than 40 mm clear above the bottom transverse reinforcement, nor less than 40 mm into compression zone of the concrete flange.

8) Where a concrete haunch is used between the steel flange and the soffit of the slab, the surface of the connector that resists separation between the two units shall be placed not less than 40 mm above the transverse reinforcement in the haunches.

9) The overall height of the connector including any hoop which is an integral part of the connector shall be at least 100 mm with a clear cover of 25 mm.

c) Cover to the shear connectors

The clear depth of concrete cover over the top of the shear connectors shall not be less than 25 mm. The horizontal clear concrete cover to any shear connector shall not be less than 50mm.

Detailing

a) The distance between the edge of the connector and the edge of the flange to which it is connected shall not be less than 25 mm.

b) The overall height of the connector, i.e., the length of the stud, diameter of the helix, height of channel, hoop etc., should not be less than 50 mm nor less than 25 mm into the compression zone of the concrete slab.

c) The diameter of the head of the stud should not be less than 1.5 times the diameter of the stud and the thickness of the head shall not be less than 0.4 times the shank diameter.

**9.2 Experimental program**

In this study, steel-concrete composite beams were fabricated on a profiled steel sheeting/decking, and threepoint bending test was conducted to study the efficacy of various strengthened beams in comparison with the unstrengthen beam.

High strength bolts were used to provide shear connection between steel beam and concrete slab. Two types of strengthening schemes were implemented. The first type focused on the flexural strengthening of the beams using CFRP or steel plate on the soffit of the steel beam, whereas the second scheme strengthened the composite beam in terms of both flexure and longitudinal stress.

For the longitudinal strengthening, high strength bolts were installed by drilling holes in the concrete slab. A total of six beams including one control were cast in the experiments where five beams were strengthened with five different strengthening schemes.

2.1 Fabrication of the specimen All the six composite beams were 2000 mm long with an overall depth of 245 mm. The height of the 150UB18 steel beam was 155 mm while the thickness of the concrete slab was 50 mm and the height of the rib of the profiled sheet was 40 mm.

The detailed dimension of the control beam is shown in Fig. 2. The effective width of the concrete slab was 500 mm. To strengthen the supporting region, 10 mm thick steel plates were welded to both ends of the steel beam covering the full cross-section (155 mm height and 75 mm width).

Two more steel plates with the same thickness (136 mm height and 34.5 mm width) were welded on both sides of the steel web at 95 mm clear distance from each end of the steel beam in order to stiffen the support regions. Accordingly, the clear span of the beam was 1.8 m.

Concrete slabs were fabricated from six batches with same mix design. Three concrete cylinders (200 mm long and 100 mm diameter) were cast for each batch to obtain the compressive strength on the day of testing of composite beams. A maximum coarse aggregate size of 7 mm was used due to the small slab thickness. All the concrete cylinders and slabs were cured in humid air (covered with wet hessian) for 28 days.

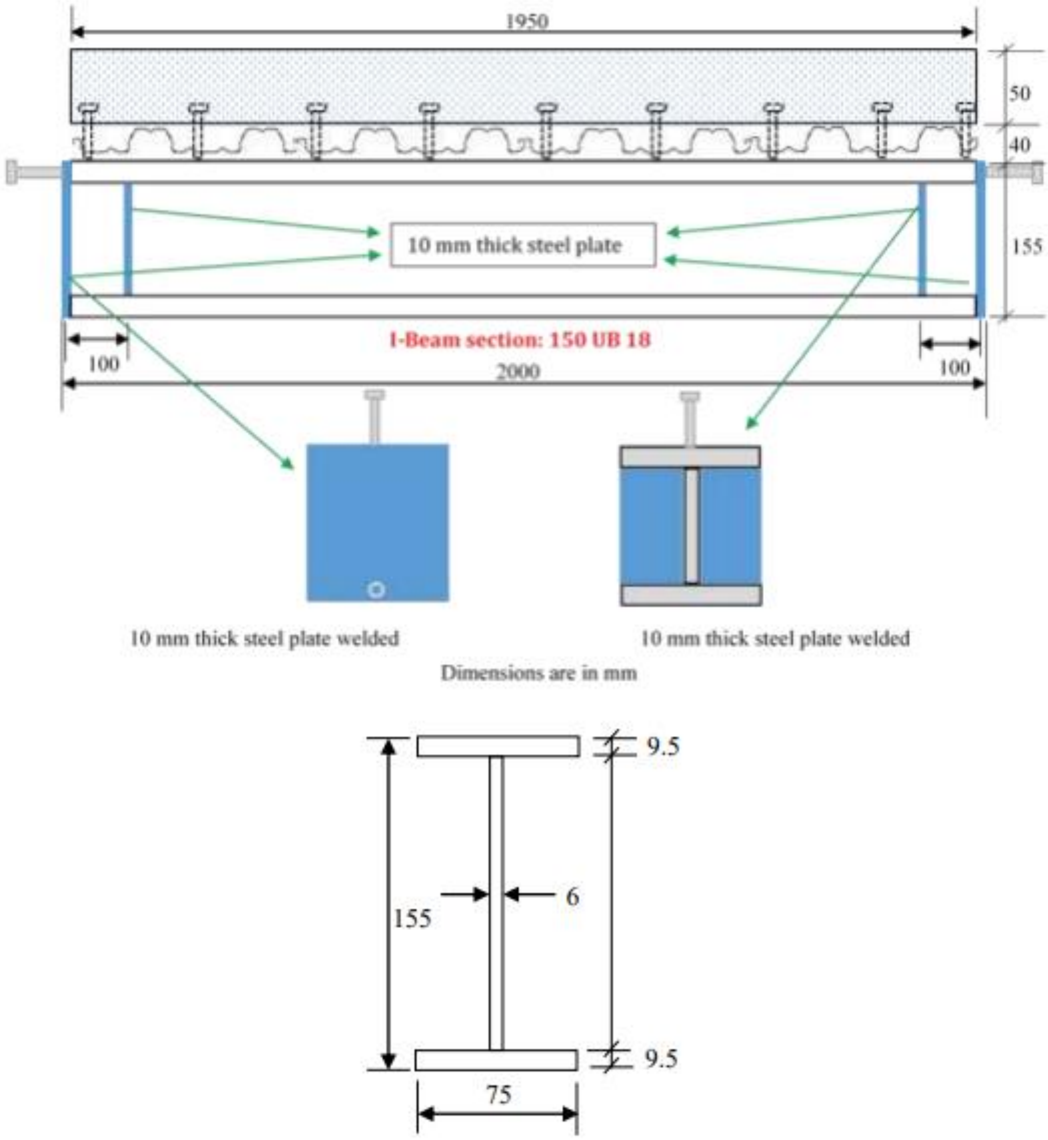


Fig. 2 Schematic of the control composite beam (not to scale)

Two shear connectors were welded at the end of the beam for lifting purpose. Spacing of the shear connectors was controlled by the centre-centre distance of the ribs of the steel deck Therefore, a total of 9 M12 grade 8.8 bolts were welded to the top flange of the steel beam in one row to provide shear connection between the steel beam and concrete slab.

The threaded part of the blot was cut and hence, the shank region of the bolt was used to provide connection between concrete slab and steel beam. The height of the shear connectors was 65 mm with a clear cover of 25 mm from the top of the concrete slab. SL81 wire mesh (8 mm bars with 100 mm spacing in both direction) was used as longitudinal and transverse reinforcement for the concrete slab.

The material properties of various components of the composite beams are as followsSteel beam: Steel beams used in the study are 150UB18.0 which has an overall depth of 155 mm, flange width of 75 mm, flange thickness of 9.5 mm and web thickness of 6.5 mm. The yield stress and tensile strength of the UB are 375 and 480 MPa, respectively, as per manufacturer’s specification. Concrete: The compressive strength of concrete was measured for all the six batches used to cast the aforementioned six composite beams. Three cylinders for each batch were prepared with a height of 200 mm and a diameter of 100 mm. The concrete cylinders were cured for 28 days in the same manner as for the concrete slabs of the composite beams.

It is evident from the table that the compressive strength varies among six beams with the lowest being 26.48 MPa (Beam 2), in contrast to the maximum value of 37.1 MPa (Beam 5). Steel reinforcement: SL81 steel mesh was used for the reinforced concrete to provide longitudinal and transverse reinforcement in the composite beams. The longitudinal steel reinforcement was placed at a clear distance of 10 mm from top of the ribs. The diameter of the SL81 mesh is 8 mm, and the centre to centre distance of the bars were 100 mm. The characteristic yield stress of the steel reinforcement is 600 MPa, while tensile strength is reported to be 700 MPa, as per manufacturer’s specification. Shear connector: M12 high strength (grade 8.8) bolts were used to provide connection between the steel beam and concrete slab. The bolts were placed at the centre of the concrete slab. The yield stress and tensile strength of the shear connector are 660 and 830 MPa, respectively, according to the manufacturer specification. Steel plate: The yield stress and ultimate strength of the steel plate used for strengthening of composite beam was 250 and 410 MPa, respectively and thickness was 10 mm. CFRP: MBrace CF 230/4900 was used in this investigation to strengthen the composite beams. The thickness of one layer CF 230/4900 is 0.17 mm, and the modulus of elasticity, ultimate tensile strength and rupture strain are 230 GPa, 4900 MPa and 2.1%, respectively (as per the manufacturer’s specification). Adhesive (CFRP-to-steel beam): MasterBrace 4500 was used to attach CFRP on steel I-beam and steel deck surface. The modulus of elasticity, ultimate strength and Poisson's ratio are 3034 MPa, 55.2 MPa and 0.4 (as per the technical data sheet from the manufacturer). Primer (CFRP-to-steel): MasterBrace P 3500 primer was used before applying CFRP to steel I-beam. The modulus of elasticity and tensile strength are 2,097 MPa and 35 MPa, respectively (as per the technical data sheet from the manufacturer). Steel Deck: The KF40 steel decking manufactured by BLUESCOPE Steel was used as a permanent formwork of the concrete slab. The properties of steel deck, obtained from manufacturer's data sheet, are provided in Table 1 and a schematic of steel deck's cross-section.

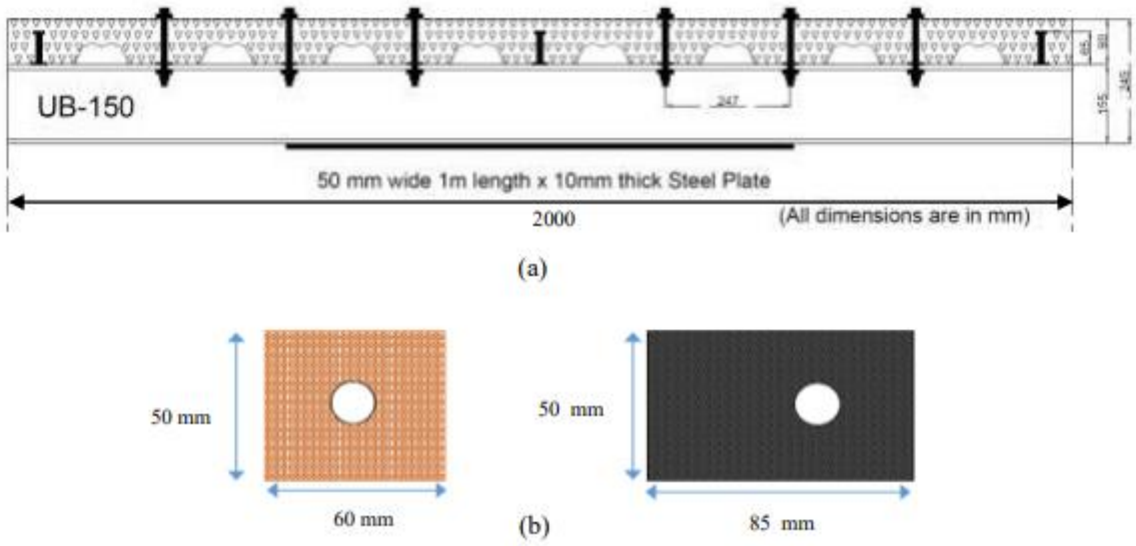


Fig. 6 (a) Strengthening of Beam 5 and (b) Steel plates used for anchoring of steel bolts in Beam 5 and 6

One beam was used as control beam (Beam 1) where no external strengthening scheme was implemented. The degree of shear connection for the control beam was 0.42. The other five beams were strengthened with five different strengthening schemes.

The description of all beams are as follows: Beam 2: This beam was strengthened using one layer of 1.2 m long x 50 mm wide CFRP sheet, and applied on the soffit of the steel deck (both overhanging sides of the steel deck). One layer of 200 mm long and 100 mm wide CFRP strip was used as transverse anchor on each end of longitudinal CFRP sheet resulting in 1 m of clear distance between two anchors (Fig. 5(a)).

No primer layer was used on steel deck before CFRP was bonded. Thin steel plates were stitch welded to the steel deck to fill the gaps between ribs (Fig. 5(b)) and to create a platform for CFRP attachment. Beam 3: Beam 3 was strengthened by welding a 1 m long and 50 mm wide steel plate to the steel I-beam.

The steel plate thickness was 10 mm. Beam 4: This beam was strengthened with one layer of 1.2 m long CFRP sheet with a width of 50 mm bonded to the steel beam's tension (or bottom) flange using the primer and epoxy.

After curing of prime layer for one day, CFRP was adhered to steel beam using epoxy resin and left for curing for seven days. Beam 5 (Hybrid 1): Beam 5 was strengthened with hybrid scheme which included strengthening of steel Ibeam by welding steel plate with the same dimension as used for Beam 3, and strengthening of concrete slab and steel deck by 12 additional 150 mm long M12 grade 8.8 steel bolts.

These bolts were drilled through the steel deck and concrete slab (6 on each side of steel I-beam) to contribute to the additional longitudinal shear capacity (Fig. 1 and Fig. 6). Each steel bolt was anchored with two steel plates (top and bottom of slab) of 60 mm × 50 mm × 10 mm dimension by nut and washer assembly (Fig. 1 and Fig. 6b).

Additional steel plates with 85 mm×50 mm × 8 mm dimension were used to clamp the steel I-beam bottom flange with the composite slab. The overlap of the steel plate and the I-beam flange was 25 mm. These additional post-installed bolts were also installed within the rib of the steel deck with a distance of 125 mm on both sides of the initially welded shear connectors.

The rib at mid-span was not strengthened in terms of longitudinal shear, since theoretically, the slip at this location should be zero. Beam 6 (Hybrid 2): Beam 6 was strengthened with the same scheme as Beam 5 except the steel I-beam was strengthened with a 1.2 m long CFRP instead of steel plate welding, as shown in Fig. 7. 2.4 Test set-up Three-point bending tests were conducted using a universal testing machine with a capacity of 500 kN.

The test was performed on all beams under displacement control at a speed of 0.6 mm/min until failure, and mid-span deflection was recorded. The test set-up of the beam is shown in Fig. 8. The end slip was measured by using a 50 mm capacity LASER to observe the relative slip between steel beam and concrete slab. In order to obtain the strain values, a total of four strain gauges were attached on each beam along the cross-section at a distance of L/4 from the support.

These four gauges were placed on top of the concrete slab (denoted as SG1), bottom of the profiled steel deck (SG2), bottom of the top flange of the steel I-beam (SG3) and on the soffit of the composite beam (SG4), as shown in Fig. 8.

Therefore, the SG4 was attached on the soffit of the steel I-beam for Beam 1 and 2, whereas SG4 was attached on the soffit of the CFRP (Beam 4 and 6) or welded steel plate (Beam 3 and 5) for the other four beams. For Beam 2, one additional strain gauges was placed on the bottom of the attached CFRP on the profiled steel deck.

Most common failure modes were the crushing of concrete, failure of shear connectors and debonding of CFRP. Fig. 10 illustrates the failure modes of the tested beams. The detail comparison and failure modes are explained below. Beam 1: The steel beam of the control beam yielded at 176 kN.

The ultimate load was recorded to be 214.14 kN where flexural failure of the composite slab was observed. At mid-span, tearing of profiled steel deck was also noticed due to bending at the deflection of 30 mm. As shown in Fig. 10(a), flexural crack initiated from bottom of the concrete slab (at the upper rib of steel deck), and the crack propagated towards the point load which ultimately led to concrete crushing at the deflection of 37 mm. Beam 2: The load deflection behaviour of Beam 2 is similar to Beam 1.

There was no improvement observed in the load-carrying capacity which reached the maximum load of 214.96 kN. However, the failure mode of Beam 2 was different than the control beam. The main mode of failure of Beam 2 was governed by a local shear failure, rapidly followed by flexural failure, occurred at the deflection of 38 mm, as illustrated in Fig. 10(b). Due to the presence of shear failure, debonding of steel deck from concrete was more prominent.

In addition, the steel deck was stiffer due to the presence of CFRP on the deck. Accordingly, the different curvature between the concrete slab and the steel deck initiated cracks at the interface that led to the debonding of this interface.

Debonding of CFRP was only noticed in the mid-span region and no complete separation of CFRP from steel deck occurred due to the fact that the debonding of steel deck from concrete slab prevented the stress transfer to CFRP. Beam 3: Beam 3 showed slightly higher stiffness in the elastic stage (steeper slope) and higher maximum load (237.46 kN) compared to Beam 1 and 2. The load - deflection behaviour showed a sudden load drop after reaching the ultimate load (at 11 mm deflection) followed by a pseudo-ductile behaviour.

This sudden drop of load was attributed to the shear connector failure. The welded steel plate on the soffit of the steel beam made the steel beam stiffer that resulted in higher load carrying capacity of the steel beam. However, due to the same number of shear connectors, the shear connectors became the weakest component.

As a result, the failure of the furthest shear connectors from mid-span were observed. After the load drop due to shear connector failure, the composite action reduced and induced more deflection of the beam with pseudo-ductile failure. At the end, the concrete slab failed due to crushing. Beam 4: Beam 4, retrofitted with CFRP attached to the bottom flange of steel beam, showed the lowest ultimate load (206.26 kN), slightly (3.68%) smaller than the control beam.

After yielding of steel (at 176 kN), the beam reached ultimate load followed by debonding of CFRP from the bottom flange of the steel I-beam which can be seen by Fig. 9 Load-deflection curves of all the beams progressive small load drops starting from 15 mm deflection as shown in Fig. 9. Finally, the compression failure of the concrete slab occurred. Beam 5: Beam 5 failed after reaching the maximum load of 302.4 kN which is the highest among all the six beams.

This beam reached its ultimate load in a more ductile manner compared to Beam 3 and 4. The longitudinal shear strengthened by additional post-installed shear connectors improved the performance of the beam in longitudinal shear significantly. Unlike Beam 3, there was no shear connector failure observed in this beam which can be expected. In addition, the debonding of steel deck from concrete slab was also prevented due to the anchorage provided by the additional bolts.

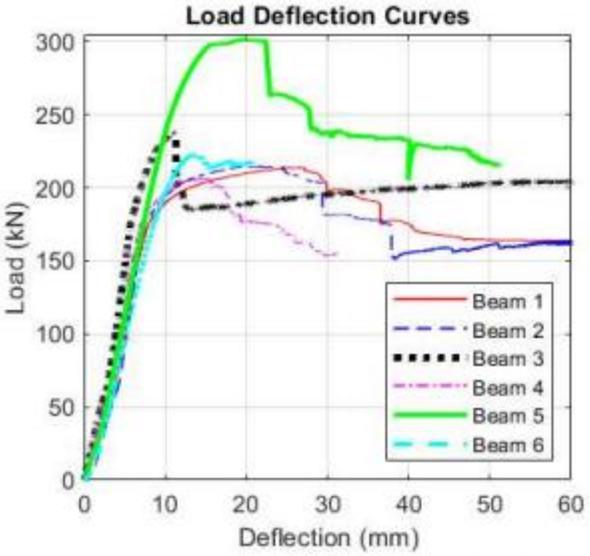


Fig. 9 Load-deflection curves of all the beams

However, the beam showed much less ductile behaviour compared to control beam and failed by concrete crushing at the deflection of 23 mm.

This is due to the fact that the concrete became the weakest component in this strengthening scheme, as both the steel beam and shear connection were strengthened, which cased sudden failure. Beam 6: Beam 6 reached its ultimate load at 222.46 kN, which is more than the control beam. However, this improvement is marginal while comparing against Beam 5. Debonding of CFRP occurred after the beam reached its ultimate load at a deflection of 15 mm. Finally, the beam failed due to concrete crushing.

Nevertheless, better composite action was achieved in this beam which will be explained later. 3.2 Ultimate load The maximum load carrying capacity and percentage difference of maximum load for all the strengthened beams compared to control beam are presented in the column 2 and 3 of Table 3. It is evident that the retrofitting of steel deck with CFRP (Beam 2) contributed to negligible increase in load carrying capacity. In addition, Beam 4, the steel I-beam retrofitted with CFRP alone, exhibited reduced ultimate load capacity. In contrast, steel beam retrofitted with steel plate (Beam 3) performed notably well (10.89% increase in peak load from control) due to the strong welded connection between the I-beam and steel plate.

The positive effect of steel plate welded scheme on the load capacity can also be proven by the performance of the hybrid strengthening scheme of Beam 5 which showed the highest increase by 41.22% compared to the control beam. Beam 6 which had hybrid strengthening scheme like Beam 5 with the exception of CFRP adhered to the I-beam's bottom flange had only 3.95% capacity improvement which is even lower than the scheme of steel plate welding to I-beam alone (Beam 3). However, the positive effect of hybrid strengthening can be observed in Beam 6 while comparing against Beam 4.

With less deflection in the plastic region that shortened the plastic region, as illustrated in Fig. 9. As a result, reduction in ductility was observed. The Beam 5 performed better compared to Beam 3 in terms of ductility due to the presence of more shear connectors.

Beam 6 had the highest reduction of ductility with an amount of 56.2% compared to the control beam. The second highest reduction of ductility (by 48.1%) was observed in Beam 3, and the reason is the failure of shear connector immediately after the steel beam started to yield. However, this beam showed a pseudo-ductile behaviour with a slight increasing slope in load-deflection diagram until 60 mm of deflection.

Beam 4 also showed 37% reduction in ductility which was much less than Beam 3; the beam only reached up to 15 mm deflection before it started to show continuous decreasing trend due to debonding of CFRP from steel beam. In short, the reduction in ductility of the strengthened beams can be related to the failure modes.

The failure mode of the control beam was the flexural failure, while the strengthened beams (except Beam 2) failed due to either concrete crushing (Beam 4, 5 and 6) or shear connector failure (Beam 3) which usually shows less ductile behaviour.

The best ductility among the five strengthened beams was observed in Beam 2 where flexural failure was observed.

However, sudden local shear failure in Beam 2 reduced ductility. 3.4 End slips Fig. 11 demonstrates the load vs. end-slip curves of strengthened and control beams. It can be observed that with the exception of Beam 4, all the strengthened beams showed lesser end slip than the same in Beam 1 in the elastic region. Beam 4 did not show considerable nonlinearity like other beams because it failed at a very low slip value of less than 1.5 mm. Similarly, Beam 2 also exhibited less slip (slightly more than 1 mm) due to the separation of steel deck from concrete slab and cracking of concrete initiated from longitudinal shear. In comparison, Beam 3, 5 and 6 can carry same amount of slip at higher load compared to Beam 1, 2 and 4 without the failure of shear connector.

The longitudinal shear strengthening scheme (of Beam 5 and 6) improved the shear transfer between the concrete slab and steel beam that resulted in higher load carrying capacity at the same slip value before the beam failed by concrete crushing. 3.5 Strain and interface differential strain The load vs. strain curve of all beams are presented in Fig. 12. The strain profiles of all the beams along the crosssection is depicted in Fig. 13.

For the strain profile, four load values are considered out of which three values are within the elastic stage and the last value is associated with the ultimate load of the corresponding beam. The presence of dual neutral axes due to partial interaction is clearly visible in case of Beam 1, 2, 4 and 5 where the concrete slab and top of steel flange show compression, while the bottom of the steel profiled sheet and bottom flange of the I-beam are subjected to tension.

In case of Beam 3, only the bottom of the steel I-beam is under tension, while all other components are in compression. For Beam 6, it is observed that up to 70 kN, the concrete slab and steel deck are in compression, while the whole steel I-beam is under tension. As the load increases, the slab, deck and top of the steel flange go into compression.

This reflects that the Beam 6 shows the best composite action. The jump at the interface is defined as interfacial differential strain and is indicative of composite action at the slab-to-beam interface (Lorenz and Stockwell 1984, Chen and Yossef 2015). As described in Fig. 14, the better composite action will have less jump in strain at the interface.

This jump in strain is calculated at four different load levels and are compared in Fig. 15. It is clear from Fig. 15 that all the strengthening techniques enhances the interfacial differential strain, while Beam 5 and 6 exhibited the lowest differential strain at the interface which was expected due to the installation of additional external bolts. And Beam 6 outperformed all other beams in terms of composite action. Beam 2 and 3 also showed significant improvement in enhancing composite action at the steel-concrete interface.

This improvement in composite action can be explained based on the works conducted by Hawileh et al. (2015) and Nawaz et al. (2016). In these works, it was concluded that flexural strengthening using CFRP increase concrete shear capacity.

Accordingly, the longitudinal shear resistance of concrete can also be expected to increase which contribute to the increased composite action between concrete slab and steel beam. It was also pointed out that CFRP is more effective in terms of increasing concrete shear strength in the beams with low steel reinforcement ratio (Hawileh et al. 2015; Nawaz et al. 2016). This explains the better composite action in Beam 6 while comparing against Beam 3 and 5 (Fig. 15), since Beam 3 and 5 has more steel in the crosssection due to the strengthening using steel plates.

### 9.3 Conclusions

This work the flexural and longitudinal strengthening of five steel-concrete composite beams with steel profiled sheet / deck and compares against one control beam.

Five strengthening schemes investigated in the study are strengthening of steel deck by CFRP sheet and end anchors, steel plate welded to steel I-beam, CFRP adhered to steel I-beam, combination of steel plate welding to steel I-beam and longitudinal shear strengthening (Hybrid 1), and combination of CFRP attached to steel I-beam and longitudinal shear strengthening (Hybrid 2). The effect of these strengthening schemes on the failure mode, ultimate load carrying capacity, end-slips and strain profile is investigated.

It is found that the combination of flexural strengthening of steel I-beam using welded steel plate and longitudinal shear strengthening of the interface using post-installed bolt attained the maximum load or moment carrying capacity. Use of steel plate alone can also enhance the maximum load carrying capacity of the composite beam.

However, the failure of shear connectors may occur if the latter method is considered. Both the hybrid strengthening schemes increases the composite action at the steel-concrete interface significantly, since differential strain at the interface was reduced by 4 to 13 times while comparing against the control beam.

However, satisfactory improvement can also be observed for the beam strengthened using steel plate only. The ductility of all the five strengthened beams are reduced compared to control beam. This is due to the fact that the aforementioned strengthening schemes lead to undesirable failure modes.

The failure mode of the control beam is the flexural failure, while the strengthened beams (except one) are failed due to either concrete crushing (three beams) or shear connector failure (one beam) which usually show less ductile behaviour.

The best ductility among the five strengthened beams is observed in the scheme where the profiled steel deck is strengthened using CFRP (but the ductility value is less than control). In this beam, the failure mode is found to be flexural-shear and lead to better ductility than other strengthened beams. More works will be conducted in future to address the issue of the undesirable failure modes.

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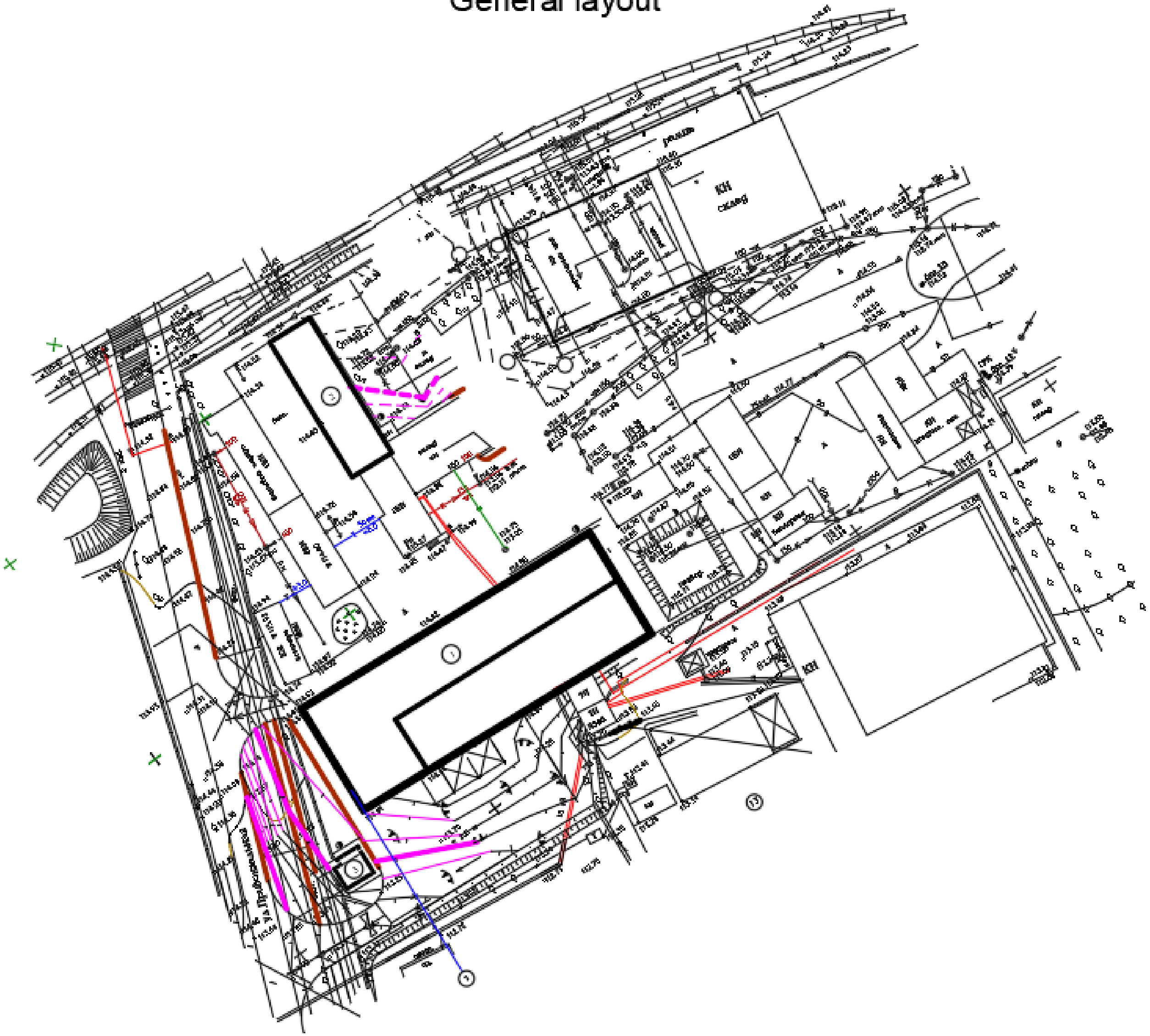
# General layout



| Chair of Computer technology in construction | National Aviation University |
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| | Architectural part |
| | General layout |
| | GW |
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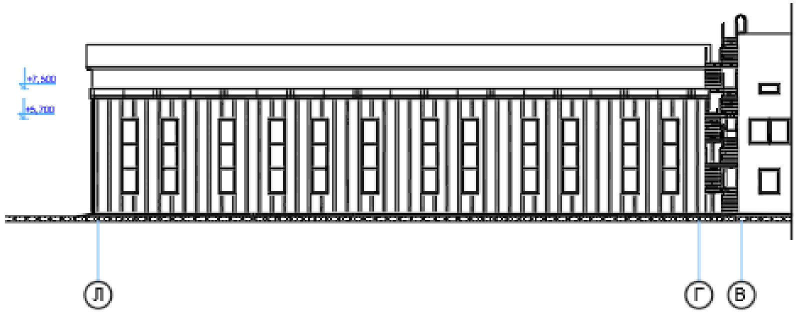
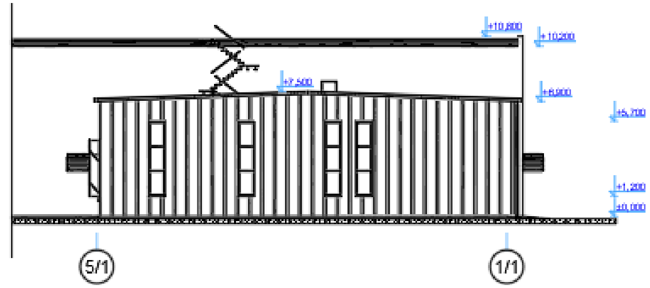
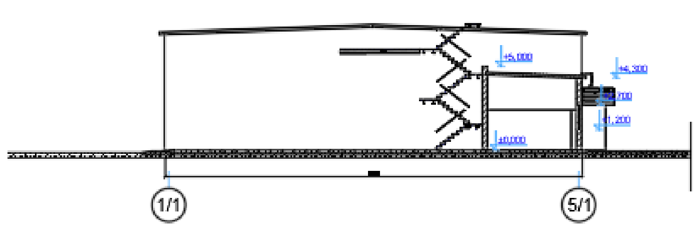
## West elevation



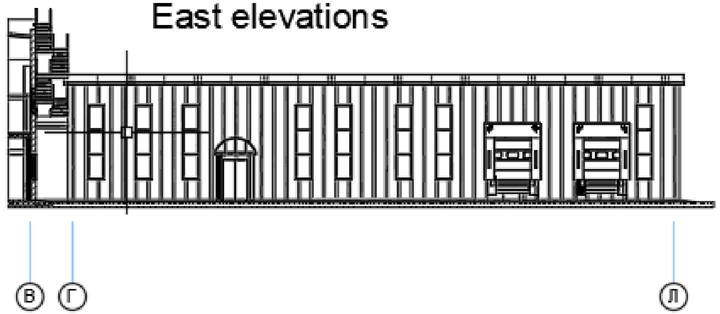

## South elevation




## Cross-section 1-1




## East elevations

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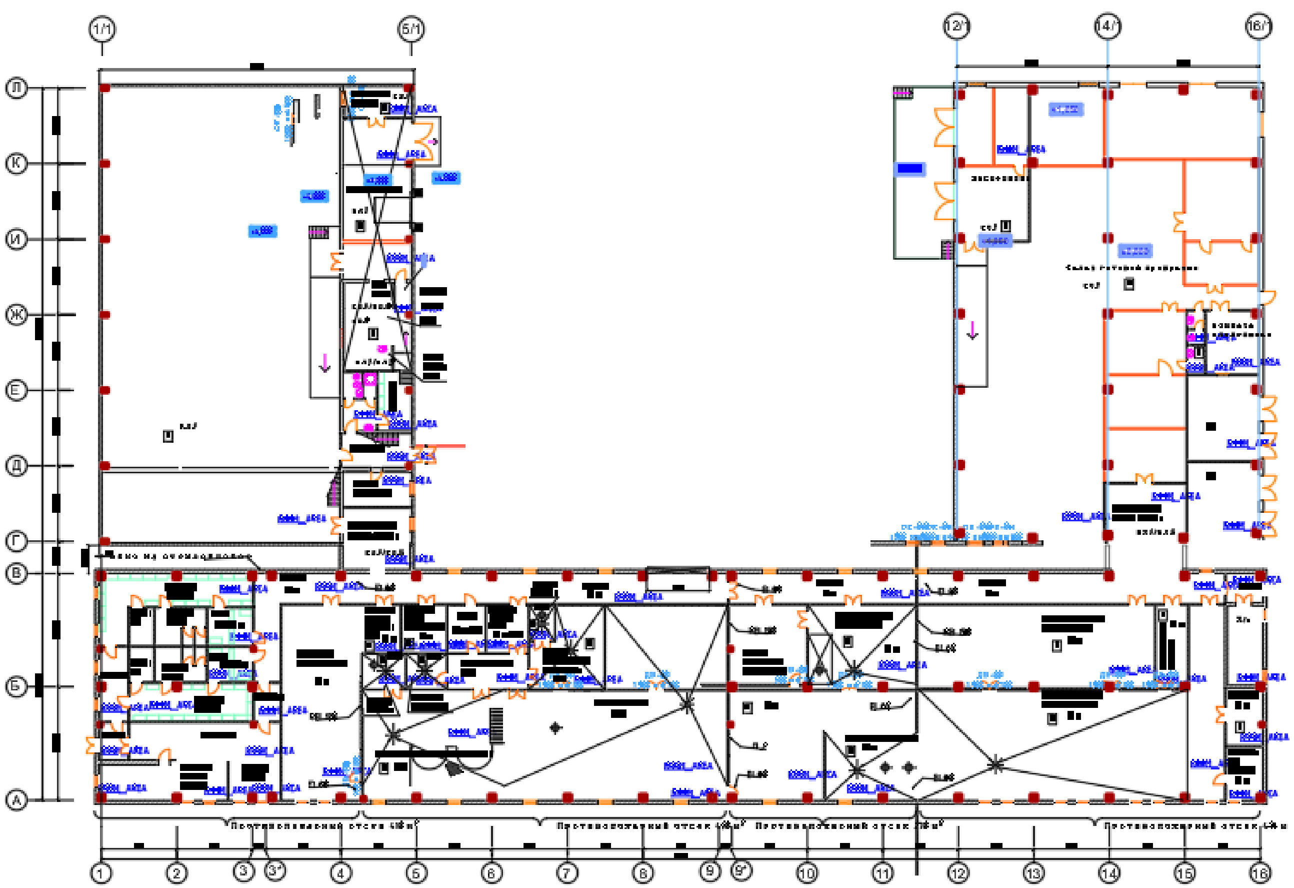
| | Architectural part |
| | Elevations |
| | DW 1 |

# 1-st floorplan

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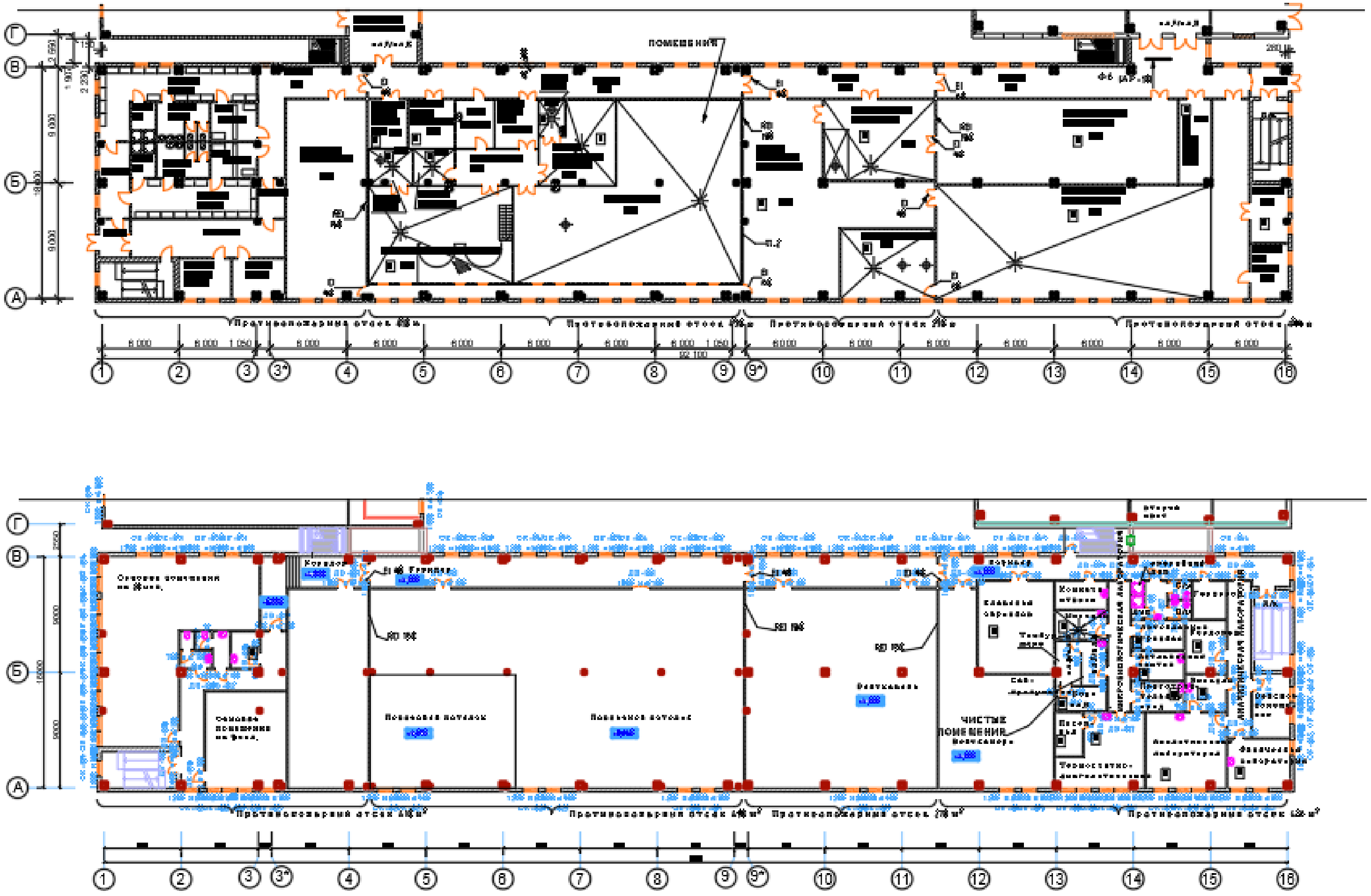
| | 1-st floorplan | | |

# 2-nd and 3rd floors



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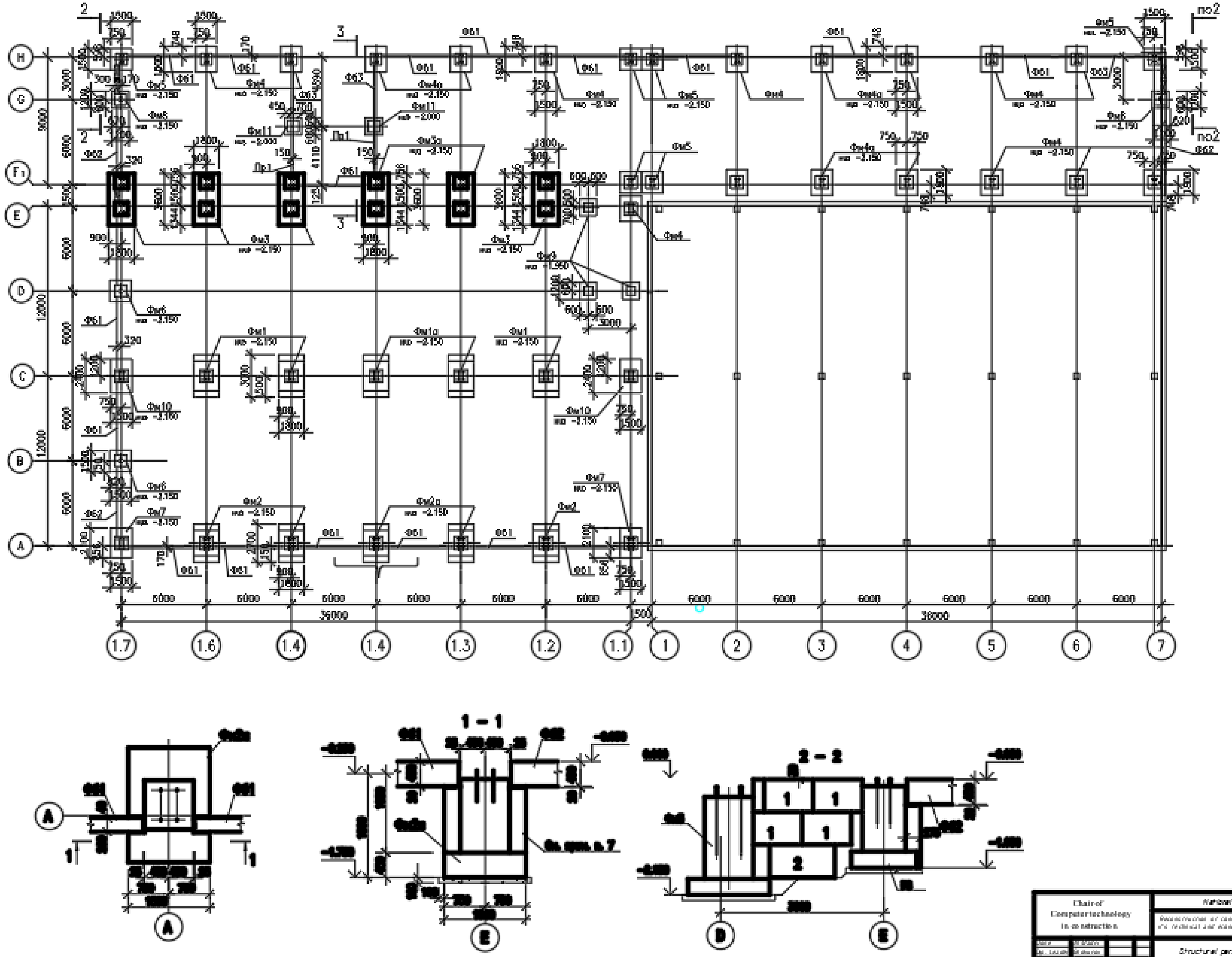
Architectural part

2nd and 3rd floors

# Plan of foundation

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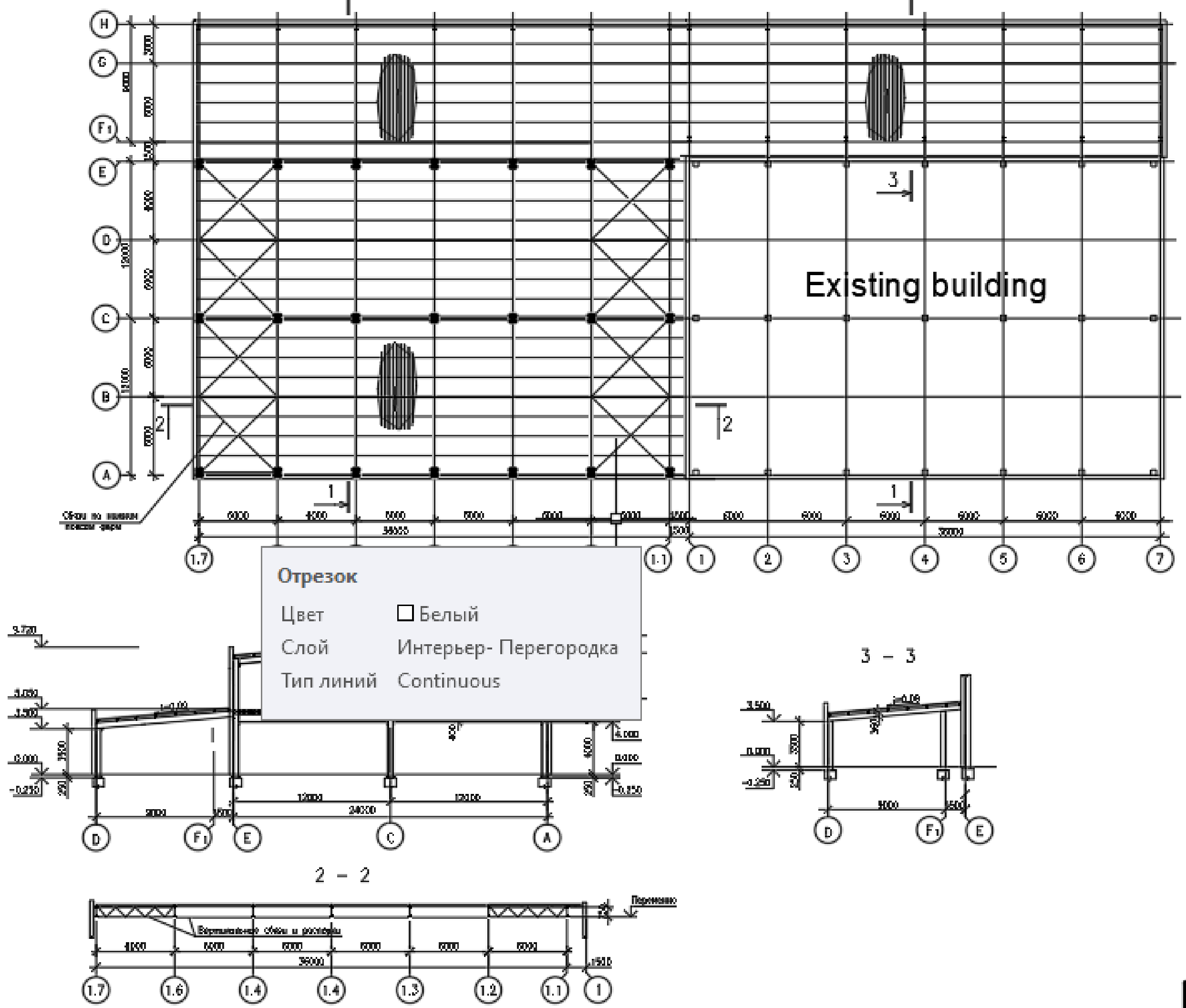
| | Structural part | DW 5 |
| | Foundation plan | |

# Plan of roof elements

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| | Reconstruction of constructed building in order to increase it's technical and economic level |
| [redacted] | Structural part / DW / 7 |
| | Plan of roof elements |