Defects of Building Structures for Landscaping

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Abstract. The article examines the defects of building constructions (bearing and fencing) in the buildings with integrated landscaping. The typological characteristics of the main defects of plant structures are provided. The paper describes the defect visual characteristics. Possible reasons for the defect occurrence are considered.

1. Introduction
Creation of such type of greenery planting as a ‘green’ building presupposes planting of greenery on roofs, facades (balconies, loggias), and interiors. Thus, a need to design a structure affected not only by external environment factors, mechanical human action, but also impact of growing plants, arises. Today there are plenty of roof systems used to arrange accessible roofs of various functions (pedestrian areas, motor-roads, parking areas, roof gardens). Issues of functional and engineering features of designing accessible roofs are considered in many scientific articles [1-6]. Depending on operational characteristics of a design building composition of a roofing pie varies.

Modern ‘green’ roof system (traditional and inversive) must include layers as follows:
1. roof slab of a building;
2. waterproofing membrane with included anti-root additives;

Figure 1. The present system of "green" roof.
3. rigid heat insulation;
4. special drainage layer, sometimes with built-in water reservoirs;
5. landscaping or filtering tissue which holds plant roots but at the same time passes through water;
6. arranged plant environment (substrate) which in general may not include ground;
7. plants specially selected for bedding on roofs (fascicular and lateral root systems are preferred).

Today experience in design and construction of such buildings is not extensive. In practice of using such buildings damages resulting in failures of a building, and surface failures that to different extends reduce quality of structures themselves, quality of internal environments in below located rooms and external part of the building.

Defectiveness of planted structures is connected with three groups of errors: design, engineering arising during construction of buildings, and operational.

Detection of defects and their reasons is a challenge as there is no legislative framework. As a rule, existing regulations related to operation of “green” roofs include general recommendations as to inspection of such structures. Thus in [7-9] include structural connections of accessible roofs, general requirements to heat and water isolation of flat roofs.

In the past Grozdov V.T. studied issues related to engineering survey of building structures, in particular balconies. [10]. Issues of accessible roof defectology were studied by German scientists Schield E., Osvald R., Rodger D., Shwarkert G. [11]. However their works did not considered impact of greenery planting on a building structure.

In 1985, we have developed methodological recommendations for the inspection of roof structures of residential buildings [12].

The operations and repairs of roofs do subject of many scientific developments. So issues of policy-making overhaul of the existing apartment buildings devoted to the work of Baltinavas N. With. [13]. Technical issues for the production of repair work involved a team of authors under the leadership of N. M. Vavula [15,16]. They contain detailed recommendations for the production of construction works, the main nodes of the pairing of building structures, methods of monitoring the quality condition of building designs of a building. However, plant design is considered only indirectly.

2. Methods
Main objective of taking measures to assess quality condition of planted structures is to get accurate information about operation of the structure under natural conditions. Data collection includes information received from design groups, builders, producers of construction materials, and employees of operation organizations based on completed defect logs and engineering reports.

An important aspect of the research is revealing weak points of the structure resulting in defect formation. It is required to consider behavior of particular construction units, and construction materials under effect of environment and aggressive plant and human effect.

As a result of system analysis of the received data classification of emerging defects and their impact on building exterior and its technical condition is possible.

The received data give information not only about facts that cause loss of structure integrity, which points are “weak”, and on which stage (design, construction, operation) errors resulting in defects are made.

The received data must be considered in further development of construction solutions of planted structures, most effective structures, forecasting of structure life, and repair (current and major) planning.

Frequently layers locating under the functional layer are subject to complete or partial failure. In this case detection of defect on the early stage of decay is almost impossible. An indicator of losing structure integrity is status of underroof elements (ceiling surface of below located rooms, wall surface, supports adjacent to elements of the considered structure). However visible signs of structure defects can be completely or partially absent on surveyed surfaces and emerge only when the structure
fails. And on the contrary, visible damages of surface layers are not a sign of forming defects of below located layers.

Thus, to obtain more complete information it is required to hold survey of planted structures by both non-destructive and destructive methods.

3. Results and Discussion

Considering the planted construction as a special case of assessable roof it is necessary to classify defects singling out traditional and caused by plant vegetation.

In course of inspection of operated, including “green” roofs a number of defects that can be classified as follows, are detected:

- Defects of supporting foundation (bend, hogging of supporting foundation, temperature deformations, complete or partial damage, erosion of structure elements);
- Defects of heat insulation;
- Roof defects (base, damp-proof course);
- Defects of exploited terrace cover;
- Defects of drain, electrical equipment elements;
- Defects of ventilation facilities;
- Defects equipment and landscaping elements.

Planting of greenery acts as an aggressor with respect to the building. Besides existing increase of loads on the building, there is a risk of losing structure integrity. These processes are first of all connected with vegetation of growing plants. In this aspect it is required to consider changes in geometry parameters of a plant, change of its weight, development of its root system, and a need of the plant in organic and mineral substances and water required for its normal life, and at the same time extremely aggressive for construction materials.

Speaking about normal operation of roof structures with integrated greenery, it is required to prevent formation of defects caused including by growth and development of plants.

Plant growth is accompanied by development of its roof system. Therefore it is necessary to provide amount of soil medium sufficient for root system of an adult plant. This aspect depends on a range of selected plants, and first of all, a type of root system.

Let’s consider main types of defects emerging in planted structures:

- Damage of the heat-insulation layer

In course of laying heat-insulation materials blistering, dampening of some heat-insulation layers, and development of putrid processes is possible. In this view use of plant-based heat-insulation materials is not allowed. Expanded polystyrene plates are recommended. Ultimate compression strength of heat-insulation materials must be chosen according to a selected range of plants.

Plant growth is accompanied by constant availability of moisture in the soil medium, thereby a possibility of developing heat insulation decay is increasing. It is connected with insufficient moisture protection of heat insulation materials during storage or heat insulation arrangement, failure to observe construction technology, and a result of damage of damp-proofing material by plant root system.

- Damage of the damp-proofing layer

Absence of the damp-proofing layer above structures considered to be leak-proof can be observed, or area of the damp may not reach edge of a structure. Such violations result in soaking of structures, mold growth, and multiple freezing-defrosting processes cause damage of a load-carrying structure of the building.

Among defects of the damp-proofing layer it should be signed out mechanical damage during construction works, molding of non-water-proof layers of damp course, leakage of rebate joints, racks of the damp-proofing layer in case of cover plate deformation, and in view of damage by root system of plants.

Adverse effect on quality of the damp-proofing layer is made by nonmoving water as a result of erosion and multiple frost penetration. Appearance of nonmoving water (exceeding needs of plants) is caused by damage of the water drain system.
• Damage of the water drain system

In view of availability of puddles on flat roof surfaces it is possible formation of racks causing roof leakage. Similar effect is observed when water intakes are located above a designed mark. As a result of the system analysis including data of planted structure research a summary table of main defects is drawn up.

Later the described defects can result in complete or partial failure of load-bearing structures of the building (Table 1).

**Table 1. Defects in structures subjected to impact plants.**

| Position | A typological view of the defect | External signs | Causes |
|----------|----------------------------------|---------------|--------|
| 1.1      | The deflection of the supporting base coating; Deflection of the load-bearing structural elements; Deformation of curved structures | Violation of the horizontal structures; Downstream deflection of the ceiling of the premises; The deflection of the coating; Change the slope of the coating; The formation of ridges upon the reference nodes; The appearance of cracks in the central part of the span | The excess of actual over estimated loads; Errors in the calculation of building structures-basics; Change the operating conditions of the building; Extreme impact |
| 1.2      | The camber of the supporting base coating; Strain bearing elements | The formation of irregularities on the coating surface; Violation of horizontality; Education gradients | The excess of actual over estimated loads; Errors in the design of the nodes of the bearing structures of the coating on the vertical bearing elements; Deformation and displacement of the vertical elements; Lack of expansion joints |
| 1.3      | Thermal deformation             | Cracks on the facade; Rejection of the cladding layers; The formation of wet spots; Destruction of the outer walls | Errors in the design |
| 1.4      | The formation of the reverse slope | Puddles of water; Bulging of the drainage funnels Education gradients | Impact of climatic factors; Errors in the design |
| 1.5      | The destruction of structural elements | The formation of cracks; Chipped, destruction of construction elements; Deflections, deformation, the violation of horizontality Wet spots, mold | Change of the functional purpose; The impact of unaccounted loads; Errors in the design; Chemical erosion materials; Violation of the technology of construction works; Defects in the upstream layers |
|   | Defects of heat insulation                                                                 | Roof defects                                                                 |
|---|-------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| b) | Defects vapor barrier                                                                       |                                                                             |
| 2  | Lack of vapor barrier;                                                                      |                                                                             |
|    | Violation of the integrity of the material;                                                |                                                                             |
|    | Offset and shift paintings;                                                                 |                                                                             |
|    | Mechanical damage of material;                                                              |                                                                             |
|    | Damage to the biological material;                                                          |                                                                             |
|    | Violation of the structure of roof                                                          |                                                                             |
|    | Condensation, mold on the ceiling downstream of the premises;                              |                                                                             |
|    | Drawdown of insulation;                                                                     |                                                                             |
|    | Destruction of the downstream materials                                                    |                                                                             |
|    | The formation of cold bridges;                                                               |                                                                             |
|    | Violation of the integrity of the vapor barrier (rebar, construction debris, equipment, plant roots) |                                                                             |
|    | Violation of technology of construction works;                                             |                                                                             |
|    | Design errors                                                                               |                                                                             |
| 2.1| Defects of the insulating layer                                                              |                                                                             |
|    | No layer;                                    |                                                                             |
|    | The destruction of the layer;                                                               |                                                                             |
|    | Chemical erosion;                                                                          |                                                                             |
|    | Mechanical damage;                                                                         |                                                                             |
|    | Biological damage;                                                                         |                                                                             |
|    | Wrong placement in the design.                                                             |                                                                             |
|    | Hydration of the material;                                                                  |                                                                             |
|    | Drawdown layer;                                                                            |                                                                             |
|    | Absence of protective layers                                                                |                                                                             |
|    | Condensation, mold on the ceiling downstream of the premises;                              |                                                                             |
|    | Freezing design;                                                                           |                                                                             |
|    | Erosion and fracture of materials roof structures;                                          |                                                                             |
|    | Drawdown of the roof surface;                                                               |                                                                             |
|    | Deformation of bearing and enclosing elements of the building-the basics                    |                                                                             |
|    | Design errors;                                                                             |                                                                             |
|    | Defects in the protective layers or their absence;                                         |                                                                             |
|    | Chemical, biological or mechanical destruction of the material;                            |                                                                             |
|    | Violation of technology of construction works;                                             |                                                                             |
|    | Failure to comply with operational requirements;                                           |                                                                             |
|    | The impact of defects of electrical equipment elements;                                     |                                                                             |
|    | Ventilation of facilities;                                                                  |                                                                             |
|    | Equipment and landscaping elements                                                          |                                                                             |
| 2.2| Defects of the protective layer                                                              |                                                                             |
|    | No layer;                                    |                                                                             |
|    | Violation of the integrity of the material;                                                |                                                                             |
|    | Offset and shift paintings;                                                                 |                                                                             |
|    | Mechanical damage of material;                                                              |                                                                             |
|    | Damage to the biological material;                                                          |                                                                             |
|    | Violation of the structure of roof                                                          |                                                                             |
|    | External signs of paragraph 2.2;                                                            |                                                                             |
|    | Cracks of the protective layer;                                                             |                                                                             |
|    | Rupture of the material of the protective layer;                                           |                                                                             |
|    | Dents, swelling of the carpet;                                                              |                                                                             |
|    | Decay                                                                                      |                                                                             |
|    | Design errors                                                                               |                                                                             |
|    | Low quality of construction works;                                                          |                                                                             |
|    | Violation of requirements of operation;                                                     |                                                                             |
|    | Deformation of bearing structures;                                                          |                                                                             |
|    | Thermal deformation;                                                                        |                                                                             |
|    | Defects in the upstream layers;                                                             |                                                                             |
|    | Damage of vegetation due to plant                                                           |                                                                             |
|    | High aggressiveness of the environment                                                      |                                                                             |
| 2.3| Defects of the base                                                                          |                                                                             |
|    | No base;                                    |                                                                             |
|    | The destruction of the base;                                                                |                                                                             |
|    | Uneven grounds;                                                                            |                                                                             |
|    | External signs of paragraph 2.2;                                                            |                                                                             |
|    | Defects in waterproofing carpet                                                            |                                                                             |
|    | Design errors                                                                               |                                                                             |
|    | Low quality of construction works;                                                          |                                                                             |
|    | Violation of requirements of operation;                                                     |                                                                             |
|    | Deformation of bearing structures;                                                          |                                                                             |
|    | Thermal deformation;                                                                       |                                                                             |
|    | Defects in the upstream layers;                                                             |                                                                             |
|    | Damage of vegetation due to plant                                                           |                                                                             |
|    | High aggressiveness of the environment                                                      |                                                                             |

3. The defects of the base
- No base;
- The destruction of the base;
- Uneven grounds
- Design errors;
- Low quality of construction works;
- Violation of requirements of operation;
- Deformation of bearing structures;
- Large concentrated loads;
- Violation of the integrity of the waterproofing
c)

| 3.2 | Defects in waterproofing carpet |
|-----|--------------------------------|
|     | • Gap;                         |
|     | • Mechanical damage;           |
|     | • Biological injury;           |
|     | • Chemical destruction;        |
|     | • Cracking;                    |
|     | • Blistering                   |

|                  | • Penetrating moisture, leaks; |
|                  | • Rotting roof structures;     |
|                  | • Erosion of materials;        |
|                  | • Drawdown of the insulating layer; |
|                  | • Deformation of the floor of the porch; |
|                  | • Swelling of the floor of the terrace |

|                  | • Damage due to vegetation;    |
|                  | • High aggressiveness of the environment; |
|                  | • Mechanical damage;           |
|                  | • Violation of technology of construction works; |
|                  | • Temperature and sediment deformation; |
|                  | • No compensating strips in the deformation joints; |
|                  | • Incompatibility of the materials used; |
|                  | • Failure to comply with the requirements for frost resistance; |

Later the described defects can result in complete or partial failure of load-bearing structures of the building.

4. Conclusions

1. When designing load-bearing structures of the building—the basics the device is integrated with the landscaping necessary to take into account additional non-permanent load, from gardening and soil. In this aspect it is necessary to consider the geometric parameters of the plant, changing its mass, root system development, as well as the need to plant organic and mineral substances and water necessary for its normal functioning.

2. Device for plant structures is necessary to consider the functional and planning aspects of the design. Also need to include measures to strengthen the supporting structures of the base of large loads (permanent or temporary).

3. In the design of plant structures must take into account the temperature and humidity conditions of the building. In this regard, the vegetation layer is an additional protection of the waterproofing from the negative impact of the external environment.

4. The impact of plants on the structure of the coating often causes defects. The reason they are violations of technology construction and installation works, and errors in the design. As a rule, the project does not provide cortadito.

5. In the design of plant structures, it is necessary to consider the biochemical effects of soil layer on the roof.

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