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Life cycle of buildings and structures. Life cycle stages

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Abstract. In this paper, the author provides provisions and definitions of the life cycle of buildings and structures. The life cycle is conventionally divided into five stages (the stage of the origin of the idea and scientific research, the formation of the design resource of constructive safety, the stage of construction (construction), the establishment of the initial (starting) resource of constructive safety, the stage of operation and its stages, the stage of technical inspection, reconstruction, strengthening and recovery, recycling stage and environmental aspects), definitions of each stage are given and conventional boundaries of each stage are proposed. In the world around us everything alive or not alive have its oven beginning and ending. The period between ending and beginning we can name as the period of existence or the period of life. We can use this abstract-philosophic statement about life period for all buildings and structures people has ever made. Some of buildings and structures made by humanity existed by ages and centuries, but other ones existed not for a long time and can disappeared from the face of the earth under the influence of set of outside and inside destructive factors.

1. Definition buildings and structures life cycle

1.1. Stages of life cycle

The period between building and structures genesis and disappearing, has a number of characteristic stages, which has differences between each other by form and content. We can attribute for this characteristic stages below:

1. The stage of the origin of the idea and scientific research, the formation of the design resource of constructive safety
2. The stage of construction, establishment of initial (starting) resource of constructive safety
3. The stage of operation and its stages
4. The stage of technical inspection, reconstruction, strengthening and recovery
5. Recycling stage and environmental aspects

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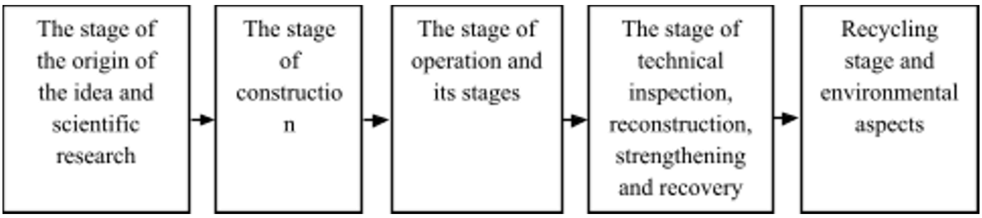

Fig. 1 Buildings and structures life cycle

1.1.1. The stage of the origin of the idea and scientific research, the formation of the design resource of constructive safety

The idea of constructing some object in a form of a building or structure appears in a ministry or department, organization or establishment with different form of owning, municipal structures or private person and in documents regulate design and constructing, named as "customer" or "client". Customer or Client, on a contractual basis, submits an application to a research and design organization to conduct scientific research and develop design estimates.

In this moment, there is not provided stages of design because of «Regulations on the composition of sections of project documentation and requirements for their content» approved by government of Kyrgyz Republic instead that it there is concept "project documentation" and "working documentation". Nevertheless we can provide the variation of design when the development of working and project documentation making in the same time in this way we can name it as a one stage design process, but if we look on variation, when the development of working documentation goes only after affirmation of project documentation, we can talk about two stage design.

The process scheme variating from type of object, category of difficulty and detalization grate. As a rule, design of a major objects for living or other civil and industrial buildings includes two stage development design (Project and working documentation). In this case first of all we must develop technical project including the results of researches based on datasets of an object of design ("project" state), and only after that we developing plans ("working project" state). In addition, in cases of developing design documentation for particularly complex unique objects, the development of a "Pre-Project Proposal" based on the results of scientific research is required.

If we have technically not difficult object, the design development underway in a one stage: we join the development technical project and working plans. In this case we developing as named as a "working project". In one stage we can develop projects for low-rise, individual houses, or public building without technical difficulties in a design, the same way in one stage we can develop design for standard buildings with minimal changes in plans.

The relations between the category of an object complexity and need for the number of design stages can be expressed as follows:

-one stage design ("working project" that includes approved part and working documentation) – use for I-III category of difficulty buildings, and for objects made by standard or reused plans

- two stage design, ("Project" and "working documentation")-use for IV and V category of difficulty buildings, or for buildings with III category of difficulty, made by individual design.

-three stage design, (pre-project agreement after results of research, “Project” and “working documentation”) – for buildings and structures V or VI category of difficulty, or as well for buildings with III category of difficulty, made by individual design, without enough technical information and documentation.

Stages of design, development project documentation order, composition and content of design: The design process conceded in three stages.

First- pre-project works (science research): collecting and preparing initial data for design, development of materials with the necessary calculations justifying the feasibility of designing new construction, reconstruction or expansion of existing enterprises.

Second- research for the appropriate design stage.

Third- the actual design in two stages of project development with a consolidated estimate of the cost of the object and working documentation, and in one stage - the development of a detailed design with a consolidated estimate of the cost of the object.

Number of stages are setting by the customer of the project in building and structure developing technical task. Two or three staging design development as usual used for very big, unique or very technically difficult objects. The later includes plants and factories which one includes basically new technologic line of manufacturing which doesn’t have analogs aboard.

Upon completion of the project development, its examination was carried out and technical documentation was drawn up in the relevant government agencies.

1.1.1.1. Formation constructive safety design resource

Calculated (design) constructive safety recourse (potential operational lifespan at the design stage) of load-bearing structures in buildings and structures is ensured by their calculation according to the design limit states (limit states of the first group and limit states of the second group) for external loads and impacts in accordance with the current building codes (SNiP), taking into account construction conditions.

1.1.1.2. Limit states of the first group

Calculation of buildings and structures by strength growth from basic provisions for calculations based on design limit states. The cross-section of the load-bearing buildings structure has the required strength if the forces from the design loads do not exceed the forces perceived by the section at the design resistances of structural materials, taking into account the corresponding operating conditions coefficients. Force from the calculated estimates T (bending moment, transverse or long force) represents a decrease in standard values, safety factors for loads and other design factors C (design scheme, coefficient of operating conditions of elements, coefficient of stability and dynamism, etc.) The force perceived by the section T_{per} is, in turn, a function of the shape and dimensions of the section S, the strength of structural materials R_{bn}, R_{sn}, the reliability coefficients for materials γ_b,γ_s the operating conditions coefficients γ_{bi},γ_{si} and the designation coefficient γ_n .

The strength condition is expressed by the inequality

$$T(g_n,\upsilon_n,\gamma_f,\gamma_n,C) \le T_{per}(S,R_{bn},\gamma_{bi},R_{sn},\gamma_{si}) \tag{1.1}$$

because the $g_n\gamma_i = g$; $v_n\gamma_i = v$; $\frac{R_{bn}}{\gamma_в} = R_b$; $\frac{R_{sn}}{\gamma_s} = R_s$ that why we can rewrite (1.1) as a

$$T(g\ ,\upsilon\ ,\gamma_n, C) \le T_{per}(S, R_b, \gamma_{bi}, R_s, \gamma_{si}) \quad (1.2)$$

1.1.1.3. Limit states of the second group

Calculation cracks formation, normal and inclined to the longitudinal axis buildings and structures load-bearing elements, is carried out to check the crack resistance of these elements, which are subject to the requirements of the first category for crack resistance, and also to determine whether cracks appear in elements, the crack resistance of which is subject to the requirements of the second and third category. It is believed that cracks normal to the longitudinal axis do not appear if the force T (bending moment or longitudinal force) from the action of external loads doesn't exceed the forces T_{crc} that can be absorbed by the section of the element

$$T \le T_{crc} \quad (1.3)$$

It is accepted that cracks inclined to the longitudinal axis of a reinforced concrete element do not appear if the main tensile stresses in the concrete of reinforced concrete structures do not exceed the calculated tensile values.

Calculation of crack openings, normal and inclined to the longitudinal axis, comes down to determining the crack opening width at the level of tensile reinforcement and comparing it with the maximum opening width

$$a_{arc} \le \quad _{crc,} \quad (1.4)$$

Calculation based on displacements consists of determining the deflection of an element due to loads, taking into account the duration of their action and comparing it with the maximum deflection at $\gamma_f = 1$

$$f \le f_u \quad (1.5)$$

Maximum deflections of load-bearing structures are set by various requirements: technological, due to the normal operation of cranes, technological installations, machines, etc.; constructive, due to the influence of neighboring elements that limit deformations; physiological; aesthetic and psychological; the need to maintain specified slopes, etc. (Table 1.1). The maximum deflections of prestressed reinforced concrete elements of buildings and structures, established by aesthetic and psychological requirements, can be increased by the height of the deflection (construction lift), if this is not limited by technological or design requirements.

There is the following procedure for taking into account loads in the calculation of deflections: when limited by technological or design requirements, the calculation is carried out for the action of constant, long-term and short-term loads; when limited by aesthetic requirements - to the effect of constant and long-term loads.

The maximum deflections of the consoles, related to the console overhangs, are assumed to be twice as large. Design standards also establish maximum deflections according to physiological requirements. Besides that, an additional calculation of instability must be performed for reinforced concrete load-bearing structures not connected to adjacent elements: floor slabs, flights of stairs, platforms, etc. the additional deflection from a short-term concentrated load of 1000 N with the most unfavorable scheme for its application should not exceed 0.7 mm.

Analyzing the structure of expressions: (1.1), (1.3), (1.4), (1.5), we can conclude that the main disadvantage of the method for calculating load-bearing structures of buildings and structures based on design limit states, regulated by current building codes and regulations, is the absence of the factor “Time" establishing such concepts as: life cycle and its stages, constructive safety resource during the life cycle, indicators that form the constructive safety resource; design, operational and residual life of constructive safety and methods for their assessment, etc.

Table 1.1 Limit deflections of load-bearing reinforced concrete elements of buildings and structures

Element	Limit deflections	Loads taken into account in the calculation $\gamma_f = 1$
Crane beams with electric cranes operating modes 4K-6K Beams, trusses, crossbars, roofing and floor slabs, open to view. *l,* m;	Technological requirements: 1/400 Aesthetic and psychological requirements:	For one crane Permanent and long-term
l =6 *l* =24 *l* =12 (at premises high less than 6 м) Curtain wall panels (when calculating from a plane) on spans: *l* < 6м 6м ≤ *l* ≤ 7,5 *l* >17,5 м	1/200 1/250 1/250 Constructive requirements: 1/200 3 см 1/250	Permanent, long-term and short-term

1.1.2. The stage of construction, establishment of initial (starting) resource of constructive safety

Conventionally, the construction stage begins after the design and estimate documentation of the building or structure being constructed, has passed all the necessary examination and zero-cycle construction and installation work has begun at the construction site. At this stage, the entire main cycle of construction and installation work is carried out.

In modern building design standards, it is conventionally accepted that the entire design load acting on the load-bearing structures of buildings and structures is applied simultaneously, although in reality the load occurs gradually as the POS and PPR are implemented. In the process of increasing the number of storeys of a building or structure, the load acting on the lower floors also increases, at the same time, the share of the increasing load on a floor-by-floor basis decreases for each subsequent floor.

In SNIP, the residual seismic safety coefficient is defined as the quotient of dividing the design seismic safety by the actual one at the time of the survey. In fact, it is worth taking into account the fact that the design seismic safety may differ from the actual one due to various circumstances (quality of construction and installation work, temperature and humidity conditions at the construction site, etc.) at the time of commissioning of the building or structure. Therefore, the indicators that were identified as a result of the survey at the time of commissioning of the facility should be taken as the initial (starting) unit of seismic safety. This makes it possible to realistically assess the rate of development of degradation processes during the life cycle and clearly represent the most probable diagram of changes in the structural safety life of load-bearing structures of buildings and structures during operation.

1.1.3. The stage of operation and its stages

At the stage of operation of load-bearing structures of buildings and structures, it is necessary to note two characteristic stages of operation: the first stage and the second stage.

1.1.3.1. First stage

The first stage with a duration of operation equal T0 time load-bearing structures adaptation i.e. time of its operation with the initial constructive safety factor $K_{red(\tau 0)}$ and operational life with reliability indices:

0.998 – established by calculation of load-bearing capacity at the design stage with the calculated characteristics of loads and structural materials $K_{red(\tau 0)} \approx 2,5$;

0.950 – established by calculation at the design stage for suitability for normal operation with standard characteristics of loads and structural materials $K_{red(\tau 0)} \approx 1,0$.

1.1.3.2. Second stage

The second stage with an operating time equal to ($T_{н.е.}$ – T_0) is the operating time of load-bearing structures of buildings and structures during which their reliability level may decrease: from 0.998 to 0.95, provided by calculations for the first group of limit states; from 0.95 to 0.90, provided, respectively, by calculations for the second group of limit states. In this case, the value of 0.90 is the threshold level of reliability for load-bearing structures of buildings and structures. In this case, the constructive safety factor $K_{red(\tau)}$can change from 2.5 to 1.0.

1.1.4. The stage of technical inspection, reconstruction, strengthening and recovery

When the level of operational life of load-bearing structures of buildings and structures reaches a value below the threshold minimum with a reliability index of 0.90, it is necessary to carry out a set of measures to strengthen and restore them in order to increase the level of serviceability to the standardized indicator. To achieve this goal, it is necessary to develop a project to strengthen and restore both an individual load-bearing element and the entire load-bearing system as a whole in accordance with current regulatory documents, practical recommendations and proposals, etc., bringing the reliability level of load-bearing structures to 0.998 and the coefficient of constructive safety $K_{red(\tau 0)} \geq 2,5$

1.1.5. Recycling stage and environmental aspects

If it is revealed that it is economically infeasible to repeatedly strengthen and restore the load-bearing structures of the building and structure in use, the latter is subject to disposal (demolition) in compliance with environmental aspects regulated by the relevant regulatory documents

2. Forecasting changes in the structural safety resource during the life cycle

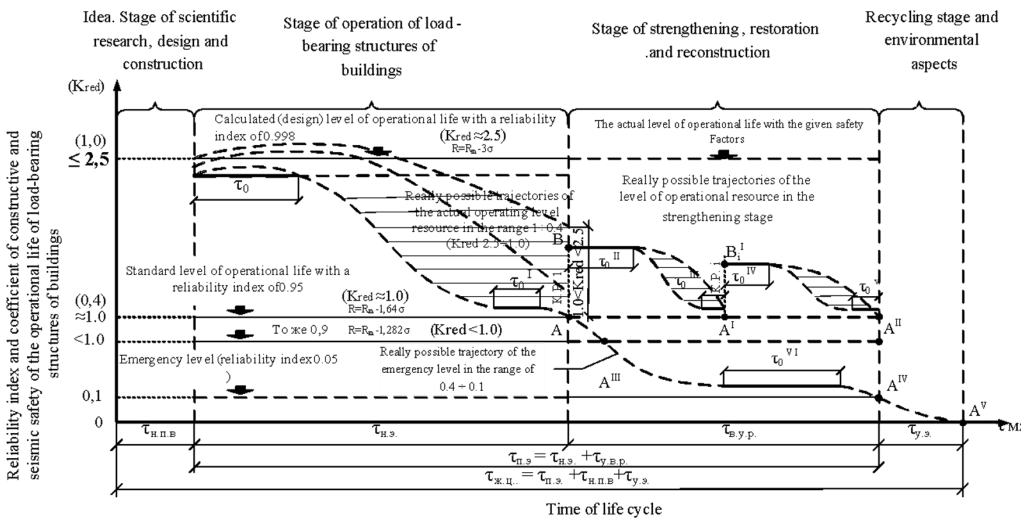

Fig. 2. Diagram of changes in the operational life of load-bearing structures buildings and structures during the life cycle

$T_{п.в}$ – design and construction stage; T_0, T^I_0, T^{II}_0 T^{III}_0, T^{IV}_0, T^V_0, T^{VI}_0 – stages of adaptation work of load-bearing structures; $T_{н.э}$ – standard (estimated) service life; $T_{в.у.р}$ – stage of restoration, strengthening and reconstruction; $T_{п.э}$ – maximum service life; $T_{у.э}$ – recycling time and environmental aspects;$T_{ж.ц}$ – life cycle tim

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