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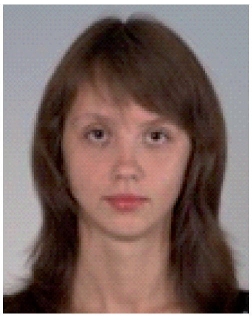

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REMARKS ON IMPROVEMENT OF DESIGNS SYSTEM FOR REINFORCED CONCRETE STRUCTURES IN CODES OF THE FUTURE

ABSTRACT. It is considered the design systems for reinforced concrete structures being used in the codes of different countries of the world, which owing to the fib activity turn out to be in harmony with Eurocodes and therefore the ones do not differ considerably, that allows to conduct the analysis of their state as some generalized designs system. It is noted the disadvantages of known design systems among of which it is distinguished according to systemology the fundamental disadvantage: wide-spread incoherentness of designs, i.e. impossibility to derive the designs under partial simple stress-strain states from designs under general complex ones, what is consequence of imperfection of empirical models of latter ones. The sources and causes of design systems disadvantages are elucidated and the most important one is showed: the non-elaborated General theory of reinforced concrete, which is put off in the future. The possible to-day ways of design systems improvement are recommended: elaboration of general enough General theory of reinforced concrete fragments. The examples of improved general designs and experimental verification of the ones are given. It is emphasized the importance for design systems improvement the Theory of plasticity, Fracture Mechanics and Direct Variation all Design Methods, which are considerably more simple for designers and students in comparison with Finite Element Method. It is stated the Plan-list of designs together with corresponding means of their improvement in codes of the future.

KEYWORDS: reinforced concrete, structures, elements, design systems, demerits, improvement means.

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ЗАУВАЖЕННЯ ЩОДО ПОКРАЩЕННЯ СИСТЕМИ ПРОЕКТУВАННЯ ДЛЯ ЗАЛІЗОБЕТОННИХ КОНСТРУКЦІЙ В НОРМАХ МАЙБУТНЬОГО

АНОТАЦІЯ. Розглядаються системи розрахунку залізобетонних конструкцій, що використовуються в нормах різних країн світу, котрі, завдяки діяльності міжнародної федерації Бетону (fib), гармонізовані з Єврономами і тому розрізняються в основах розрахунку не суттєво, що дозволяє провести аналіз їх стану як деякої узагальненої системи розрахунків. Відмічаються недоліки відомих систем розрахунку (СР) серед яких можна виділити відповідно до Системології фундаментальний недолік: широко розповсюджена непов'язаність розрахунків, тобто неможливість виводу розрахунків при простих окремих напружено-деформованих станах (НДС) з розрахунків при загальних складних НДС, що є наслідком недосконалості емпіричних моделей останніх. Джерела та причини недоліків СР з'ясовуються та виділяється основний з них: нерозробленість загальної теорії залізобетону (ЗТЗБ), котра відкладається на майбутнє, внаслідок недостатнього вивчення ряду проблем, зокрема, фізичних залежностей бетону, моделей зчеплення арматури з бетоном та ін. Рекомендуються можливі на сьогодні шляхи вдосконалення СР: розробка достатньо загальних фрагментів ЗТЗБ. Приводяться приклади вдосконалених загальних розрахунків та результати їх експериментальної перевірки. Підкреслюється важливість для вдосконалення СР використання Теорії пластичності та Механіки крихкого руйнування, а також Прямих варіаційних методів розрахунку, котрі за комп'ютерної реалізації значно простіші для проектувальників і студентів порівняно з Методом Скінченних Елементів (МСЕ).

КЛЮЧОВІ СЛОВА: залізобетон, конструкції, елементи, недоліки, засоби вдосконалення, системи розрахунків.

1. PROBLEM FORMULATION: SOME DEMERITS OF KNOWN DESIGN SYSTEMS

1.1 Insufficient accuracy of models of RC elements (RCE) and structures (RCS) under multiaxial SSS. These models are as rule empirical and noted demerit is displayed as partial or even complete incoherence of designs under simple (partial) and complex (general) SSS, that leads to impossibility of derivation of partial designs from general ones. For example, in codes of all countries of the world it is impossible to obtain the known strength design of RCE cross section under bending moment M action only from the more general strength design of RCE under action of shear force Q jointly with moment M because the being used models of latter design are so imperfect that transition to partial design by $Q=0$, $M\neq0$ is impossible. It is usually not paid attention to the noted demerit. However according to the Systemology [1] perfect enough system has well developed connections between its elements. Therefore the comparatively perfect system of RCS designs ought to possess the connections between designs by partial and general SSS and the absence of these connections witnesses the insufficient high development level such designs system. The noted demerit is most fundamental and the one involves many partial demerits.

1.2. Non-optimality of RCE strength design under action of shear force Q based on the truss model with destruction of the concrete compressed «strut» between regular inclined cracks in the RCE web. The noted destruction is observed in tests [2, 3] in comparatively narrow domain: that are RCE of T- and 2T – section with thin enough web $b_w/h=0{,}06\text{-}0{,}15$. Yet the web thickness of RCE is often by far much than noted one and the strength on concrete strut is so great that danger of respective destruction is absent practically. Then design of lateral reinforcement by the model of concrete strut failure leads to very great intensity of the one. However such reinforcement is not needed really because the RCE with usual web thickness are failure by the Dangerous Inclined Crack (DIC), the model of which must be basis for design of lateral reinforcement. When the DIC is developed the lateral reinforcement resistance is used completely what is not characteristic of destruction on crushing of concrete strut.

In general the strength design model of bar element under the forces M, Q, N action must correspond to its reinforcing group in accordance with elements classification [4] depending on quantity of longitudinal and lateral reinforcement, respective behavior under loading and failure type (Fig. 1).

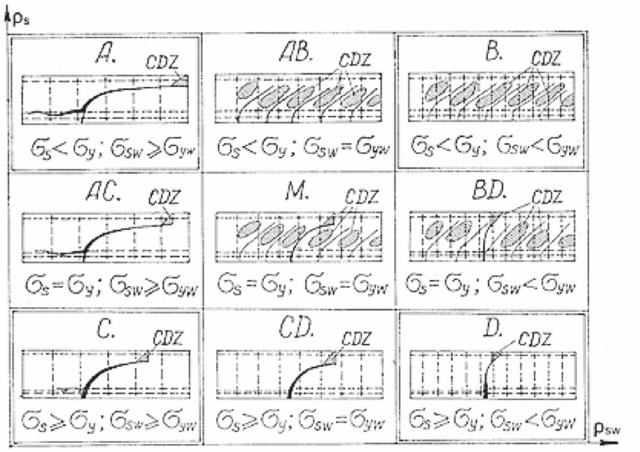

Fig. 1. RC element classification:
ρs, ρsw – respectively longitudinal tensile and lateral reinforcement ratio,
σs, σsw – respective reinforcement stress,
CDZ – concrete destruction zone.

This classification allows to distinguish the group of elements C with most economical expense of all reinforcement – longitudinal and lateral. The existence of the pointed out elements pushed to working out of the Optimization Strength Theory of RC Elements under joint action of the M, Q, N forces [5].

1.3. Inexactness of Deformation Strength Criterion (DSC) in designs of RCE cross sections under action of the M and N forces.

This criterion is used in codes of many countries and the one is kept in MC 2010. According to DSC the failure state of cross section is come when concrete fiber strain on the RCE compressed side reaches the so called «ultimate strain ε_{cu} ». In codes the ε_{cu} values are set depending on concrete strength f_c only and the ones change on interval 3,5-2,8 ‰ being decreased with f_c increase. The mentioned above ε_{cu} values correspond approximately to the measured ones in being tested beams and eccentrically compressed RCE with large enough eccentricities e_0 of axial force N. But when the e_0 is decreased and $e_0 \to 0$ the value $\varepsilon_{cu} \to \varepsilon_{c1}$, where ε_{c1} is the concrete ultimate strain under axial compression, which is considerably smaller than under bending and eccentrical compression. Thus the strength design of RCE cross sections with the DSC use can't take into account the gradual change of concrete ultimate strain ε_{cu} when transition from bending to axial compression. According to experiments the ε_{cu} depends on, except concrete strength and section SSS character, also from section shape, type of steel tension diagram, tensile and compressed reinforcement quantity, prestressing et al. The influence of the pointed out factors on the ε_{cu} can be taken into account if the inexact DSC will be substituted by the force Extreme Strength Criterion (ESC) [6].

2. ANALYSIS OF NEW RESEARCHES: SOURCES AND CAUSES OF DEMERITS OF RCS DESIGN SYSTEMS.

2.1. Information outburst and empiricism dominance. The concrete and RC complicated properties, being distinguished considerably from properties of traditional constructive materials, apparently, are still not studied and realized completely enough. In such conditions it is necessary and it takes place the continuous process of experimental investigations of concrete and RC leading to growing volume of information i.e. to information outburst. Herewith the obtained experimental data are mostly used in the form of empirical relations and designs leading to the empiricism dominance.

Empirical way of designs receipt, which is characteristic of the first development stage of all branches of sciences and technics, is laborious, material-spent and expensive especially under multiaxial non-uniform SSS. This way not always allows to reveal all determining factors which influence on structures behavior. The obtained relations are partial with limited by experiment conditions the application domain which is not always clearly determined. That is why on the basis of empirical relationships it is impossible the complete enough optimization of structures and their reliability guarantee.

2.2. Non-elaborated General Theory of RC (GTRC). The history of sciences and technics [7, 8] shows that the empiricism period can be replaced by the period of General Scientific theory development as higher form of generalization and systematization of reached knowledge. The role of GT is displayed in explanation of mechanism and physical reality of known phenomena, connection between phenomena being seemed independent and incompatible ones. Most important role of GT is the prediction of the new earlier non-observed phenomena. Yet the elaboration of the GTRC is highly difficult and long process demanding the profound knowledge of concrete and RC specific properties which must be expressed by means of generalized statements in the form of mathematical wordings [9]. However at present it is compelled to admit that GTRC is kept as the cause of the future in consequence of some problems which are still not solved with needed completeness. In spite of numerous suggestions the ground of the concrete physical relationships $\sigma_{ij} - \varepsilon_{ij}$ under multiaxial SSS is first of all such problem.

2.3. Insufficient realizing of the concrete strength properties.

2.3.1. Inexact notion about role of descending branch of concrete physical relation $\sigma_{ij} - \varepsilon_{ij}$. This notion arose in connection with strength design of RCE cross section. Herewith it is usually thought that role of stress σ_c distribution along concrete compressed zone height x by the curve with descending branch is reduced to the making more precise of σ_c distribution in comparison with being used often the simplified distribution: rectangular, parabola-rectangle, bi-linear. Apparently the pointed out substitution leads to very small making more precise of the resultant force N_c in concrete compressed zone, lever arm of internal forces Z and ultimate load parameter M_u or N_u in the case when the section is non-overreinforced and reinforcement steel has the yielding plateau. In this case in consequence of design complication the introduction of stresses distribution by the curve with descending branch losses the common sense even in comparison with simplest rectangular distribution which leads to sufficient design closeness with tests in pointed out case.

Situation radically changes when we intend to obtain the general method of strength design of RC cross sections which is applicable to both underreinforced and overreinforced sections, for reinforcement steel of both physical and conditional yielding limit, both under bending and eccentrical compression by any eccentricity value of axial force $0 \le e_0 \to \infty$.

Consideration of such general design method demands to use the complete compression diagram $\sigma_c - \varepsilon_c$ with descending branch of concrete and the one leads to the new result [6]: introduction necessity of the force Extreme Strength Criterion (ESC) instead of the DSC. The conducted analysis reveals the specific stresses σ_c redistribution on the concrete compressed zone x which is accompanied by the disstrengthening of more deformed part near RCE compressed side and stresses increase near zero line of σ_c stresses. At the beginning the pointed out stresses redistribution restrains from failure of more deformed concrete part, thanks to that the strain ε_{cm}

of RCE compressed side exceeds the concrete limit strain ε_{c1} under axial compression and the continues to be enhanced together with load up to achievement of ultimate strain $\varepsilon_{cu}>\varepsilon_{c1}$. Thus on the interval $\varepsilon_{c1}\leq\varepsilon_{cm}\leq\varepsilon_{cu}$ bearing capacity of section grows up and the most strained compressed concrete part experiences so called «natural rigid loading». At the moment $\varepsilon_{cm}=\varepsilon_{cu}$ the ultimate load parameter F_u (M_u or N_u) reaches the strict maximum and the ESC is displayed

$$F_u\left(\varepsilon_{cm}\right)\Big|_{\varepsilon_{cm}=\varepsilon_{cu}} = \max \qquad (1)$$

After maximum the curve «load parameter F – fibre strain ε_{cm}» comes on the descending branch and if the load is not decreased the sudden failure of compressed concrete and entire section happens by some stress σ_s in tensile and σ_s' in compressed reinforcement. It is important to emphasize that display of descending branch of concrete relation σ_s – ε_c, specific stresses redistribution on concrete compressed zone height x, natural rigid loading of disstrengthening compressed concrete part and the ESC are mutually connected phenomena which together express specific pseudo-plastic properties of concrete.

2.3.2. Insufficient clear division of the RCE behavior into brittle, pseudo-plastic and plastic cases under multiaxial SSS. Important peculiarity of concrete properties is displayed as dependence of its behavior character under load from sign and value of middle (hydrostatic) stress σ [10]. By tensile $\sigma>0$ before ultimate behavior of concrete is close to elastic one and the coming of ultimate state is connected with development of the structural defects in the form of initial (often near surfaced) microcracks, which under small enough load grow up stably. One microcrack (dangerous) earlier than others reaches the some critical length l_{cr} and turns into rupture macrocrack on the level of ultimate load. The dangerous crack is instable and the one instantaneously spreads, divides structure on parts leading to brittle failure (Fig. 2), which is described by the Fracture Mechanics [11].

By mean values of compressed stresses $\sigma<0$ (most often meeting in the RCS) concrete displays in before ultimate states the pseudo-plasticity with characteristic dilatancy, conditioned by the development in concrete the disperse system of microcracks. Herewith in failure stage it is revealed the descending branch of concrete relations σ_{ij} – ε_{ij} and the ultimate load is determined by the ESC. Under high compressed $\sigma<0$ the microcracks do not develop, the dilatancy is absent and concrete behavior in ultimate stage is close to plastic one. Thus in depending on sign and value σ the adapted to concrete Fracture Mechanics, Elasticity Theory and Plasticity Theory with its versions of physical relations may be as basic for working out of RCS designs on Ultimate and Serviceability limit states.

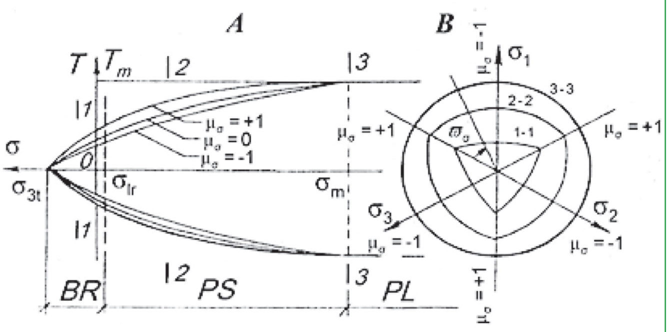

Fig. 2. Concrete strength surface in cylindrical coordinates σ, T and ω_σ or μ_σ with meridional (A) and deviation (B) sections. BR, PS, PL – intervals of brittle, pseudo-plastic and plastic concrete behavior respectively.

TASK FORMULATING: AT PRESENT POSSIBLE WAYS OF IMPROVEMENT OF RCS DESIGNS SYSTEM. EXAMPLES OF IMPROVED GENERAL DESIGNS

The stated above analysis shows that principal means of achievement of perfect enough RCS designs system is General Theory of RC (GTRC) [9] elaboration of which by objective reasons is put off on the future. Keeping the GTRC development as most important strategic aim of investigations in the RCS domain, it is necessary to formulate the relevant for present conditions the tactics of improvement of RCS designs system. In our opinion this tactics must be the working out of the GTRC fragments, which are distinguished by the considerable generality allowing to solve wide enough circle of problems. GTRC fragments reflect to some extent partial SSS and take into account certain intensity of reinforcement, influencing on the RCS deformation character (Fig.1). Therefore the partial approximate models of concrete, conforming with experiments can be used for the GTRC fragments. As examples of GTRC fragments may be the next ones.

3.1. Strength design of the RCE cross sections under action of M and N forces on the base of deformation model with the ESC [6]. This design does not introduce any empiric relations and uses only the equations of continuum Mechanics: static, geometric as plane section hypothesis and physical relationships of used concrete and reinforcement. General method [6] allows to find from design all parameters of ultimate state of RCE section regarding stresses and strains of concrete, tensile and compressed reinforcement, geometric quantities. The concrete ultimate strain of RCE compressed side ε_{cu} is obtained also from design as one of unknown values. The design [6] takes into account influence on the εcu not only concrete strength but also section SSS character, section shape, type of reinforcement tension diagram, quantity of tensile and compressed reinforcement, prestressing intensity et al., that is conformed with tests.

3.2. Optimization Strength Theory of RCE (OSTRCE) under joint action of the M,Q,N forces [5]. This theory is general for strength design both on inclined and normal (cross) sections (cracks) i.e. unlike known design systems the one allows to derive the partial design from general one. This fact witnesses about more high development level of OSTRCE in comparison with known designs. The OSTRCE secures most economical reinforcement steel expense and plastic failure as on normal (cross) as inclined cracks.

3.3. Elementary Mechanics of Pseudo-plastic Ultimate State of Concrete (EMPS) [10]. This analysis draws attention to the fact that many practically important strength problems of concrete and RC elements under multiaxial SSS can be solved with sufficient accuracy on the basis of known Theory of perfect plasticity [12, 13]. Such possibility takes place for different cases of shear, cut, crushing-splitting, punching shear, pressing out, failure of reinforcement anchorage, failure of different indirect reinforcement et al. (Fig. 3).

Applicability of perfect plasticity theory is limited by the «Applicability conditions» which are formulated and illustrated by the examples [10]. The important peculiarity of strength designs [13] is the use of Direct Variational Method and velocities field with gap (leap) on the some surface S_l in volume V of considered element. The velocities gaps are admitted as in tangential ΔV_t as in normal ΔV_n directions to the S_l surface in consequence of volume deformation (dilatancy) of concrete. Design is connected with analysis of minimum of functional J corresponding to Variational Principle of virtual velocities V_i [14]. Functional J is simply calculated by the plasticity condition [15] on the base of which the solutions of many strength problems were obtained [4, 13, 16-22].

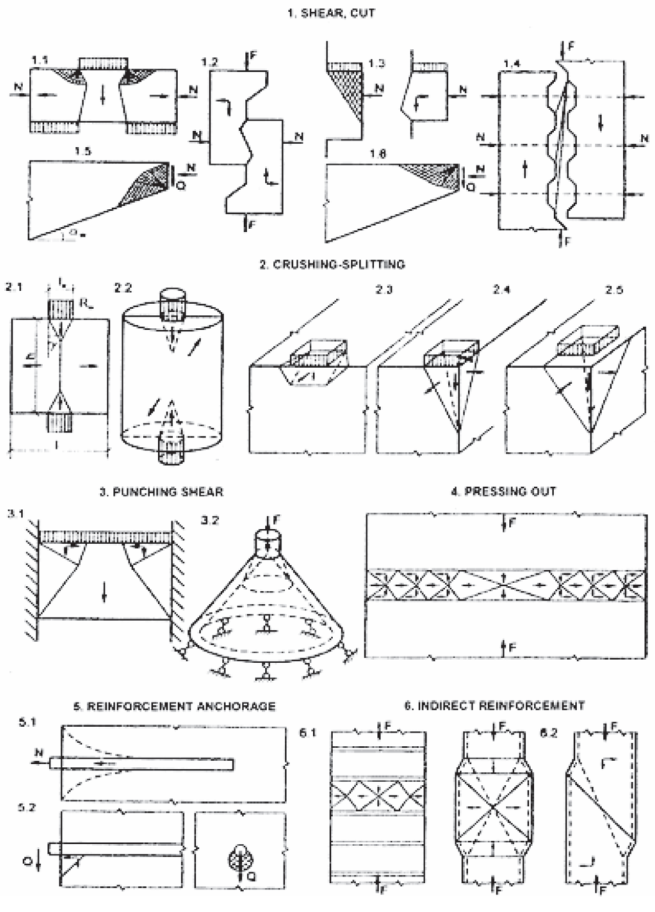

Fig. 3. Characteristic elements groups with destruction schemes according to [13, 16, 17]. The arrows without notation show the velocity of elementary respective parts.

In particular for 2D SSS the functional J is written down in general case of dynamic problems so

$$J=\int_{S_l}\left\{\begin{array}{l} m\left[2B\left(1+0,25\left(\Delta V_t'/\Delta V_n\right)^2\right)^{\frac{1}{2}}-1\right]\times \\ \times\Delta V_n'+\rho\left(\Delta V_n' V_n' V_n'+\Delta V_t' V_n' V_t'\right)\end{array}\right\} dS \quad (2)$$

where

$$B=1/3+\left(T_{sh}/m\right)^2,\quad T_{sh}^2=f_c f_{ct}/3,\quad m=f_c-f_{ct} \quad (3)$$

ρ - concrete density, $\Delta V_t', \Delta V_n'$ - gaps (leaps) of velocity components respectively in tangential t and normal n to the surface Sl directions, V_t', V_n' - mean values of respective velocity components on both sides of S_l surface in some its point. For taking into account of reinforcement influence on RCE strength the functional (2) is supplemented by the particular item J_s reflecting the virtual power of reinforcement internal forces in the crossing places of reinforcement with the surface S_l. The item J_s is turned out to be expressed also through gaps of velocity components. The procedure of ultimate load design includes the next actions:

1) choice of the shape of velocities gap surface S_l i.e. choice of cinematic failure mechanism of considered element;
2) composition of the functional (2) for choose cinematic mechanism and receipt from condition $J=0$ of load parameter F expression through unknown geometric parameters $G_k (K=1,2,\dots m)$ of failure surface S_l and velocities ratios $K_l=V_i/V_j\ (l=1,2,\dots n)$ of element parts $i, j=1,2,\dots p$, divided by the surface S_l.
3) determination of unknown parameters G_k and K_l from condition of minimum of load parameter $F(G_k, K_l)=min$;
4) calculation of ultimate load parameter F_u by the found G_k and K_l.

For example in plane problem of two-sided crushing-splitting of concrete slab the cinematic failure mechanism includes (Fig. 4,a) two being drawn together with velocities V_2 and $-V_2$ isosceles triangular parts 2 with angle γ between axis y and equal sides and two parts 1 mutually being dispersed with (Fig. 4,a) velocities V_1 and $-V_1$. The straight lines dividing parts 1 and 2 form the velocities gap surface (line) S_l. The unknown parameters tgγ and $K=V_1/V_2$ are found from minimum condition of ultimate crushing stress f_{cr} [13, 18]

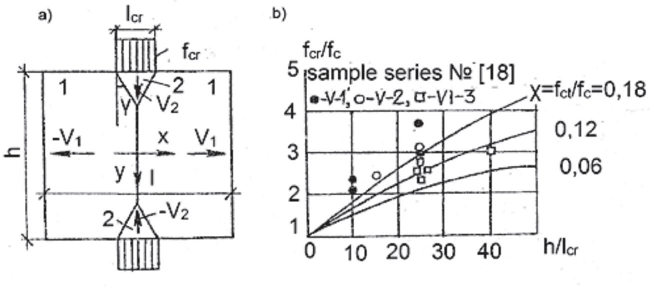

Fig. 4. Failure scheme of concrete slab under two-sided crushing-splitting (a) and comparison of theoretic curves with experimental points [18] (b).

$$f_{cr}/m=\left\{2B\left[\left(K-tg\gamma\right)^2+0,25\left(Ktg\gamma-1\right)^2\right]^{\frac{1}{2}}-\left(K-tg\gamma\right)\right\}\left(1/tg\gamma\right)$$
$$+\left(f_{ct}K/m\right)\left(\alpha tg\gamma-1\right)/tg\gamma, \qquad (4)$$

where

$\alpha=h/l_{cr}$, h, l_{cr} are showed on Fig. 4,a.

The strength curves (4) are obtained close enough to experimental points [18] (Fig. 4,b).

The given example shows the merits of the offered method:

comparative simplicity, clearness and obviousness of failure schemes lightening the mastering of the one by designers and students, application of simple known optimization software in table processor MS Excel, acceptable exactness.

However this method is first of all applicable to simple enough one-coherent structures and elements, which are spread far and wide in practice. In the cases of complicated multi-coherent structures it is completed to use the FEM with expensive software.

3.3.1. Comparison of the theoretical strength by the EMPS with experimental one. The criterion of completeness of experimental verification was considered as main by the analysis of EMPS applicability to ultimate load design. Therefore for EMPS verification the wide enough elements totality with various SSS was attracted. With this aim the groups elements (Fig. 3) were used: shear and cut [16, 17, 20], crushing-splitting and punching shear [18], indirect reinforcement including the concrete filled steel tubular elements [21] and others. It was obtained the following averaged indexes – mean ratio M of test ultimate load F^{test} to theoretic F^{calc} and variation factor V of this ratio for the groups elements: 1) shear and cut – M=0,992, V=12,71%; 2) crushing-splitting – M=1,005, V=11,52%; 3) punching shear – M=1,010, V=8,0%; 4) indirect reinforcement – M=0,962, V=4,625%. The given data witness that EMPS leads to sufficient for practice accuracy by determination of ultimate load of concrete and RC structures and elements under multiaxial non-uniform SSS.

PRIMARY RESULTS STATING: FOUR CORNER-STONES OF RCS DS IMPROVEMENT

The possibility of brittle, pseudo-plastic and plastic behavior of concrete and RC elements allows to emphasize the importance of four means for RCS DS improvement:

- theory of perfect plasticity used by the conditions of its applicability with taking into account of concrete and RC properties;
- Fracture Mechanics adapted to concrete and RC properties;
- Direct Variational Methods of problems solving;
- Method of section in theory of cracks.

4.1. The taking into account of concrete and RC properties in Theory of perfect plasticity. Herewith it is meant the next:

1) use of plasticity (strength) condition which conforms well with tests;
2) application of reinforcement intensity securing the complete use of its resistance into all directions and respective plastic behavior of RCS in failure state;
3) control of the applicability conditions of perfect plasticity model [10] and introduction (when it is necessary) of correction factor taking into account the decrease of concrete plasticity with increase its strength [22].

4.2. Brittle failure criterion of concrete. In our opinion the concrete is brittle enough material so that designs with use of Fracture Mechanics can be conducted on the basis of critical stress intensity factor K_{IC} or fracture energy G_{IC} found from reliable experiments. The pointed out designs of concrete and RC elements lead to satisfactory proximity of theoretic strength to test one if the values K_{IC} were found on the specimens of sufficient dimensions and if the stable growing up of the initial notches was taken into account. When the stable growing up of the specimen notch is taken into account the K_{IC} values obtained by different authors turn out to be close.

For use of Fracture Mechanics to RCS it is necessary first of all the K_{IC} depending on concrete strength. Such relationship was obtained in the experiments [4, 24] data of which are highly close. We recommend the following relations for usual heavy concrete [25]

$$K_{IC}=0,09 f_{c,cube}^{0,75} \text{ by } f_{c,cube}\le 35\,MPa, \qquad (5)$$

$$K_{IC}=0,539 f_{c,cube}^{0,25} \text{ by } f_{c,cube}\ge 35\,MPa, \qquad (6)$$

for claydite concrete

$$K_{IC}=0,056 f_{c,cube}^{0,75} \text{ by } f_{c,cube}<60\,MPa, \qquad (7)$$

where concrete cube strength $f_{c,\ cube}$ in MPa, K_{IC} in MPa·m^{0,5}.

The experimental determination of K_{IC} is more easy than G_{IC} one [26]. Herewith the recalculation from K_{IC} to G_{IC} and back meets the difficulties connected with change of the deformation modulus of tensile concrete in ultimate state near crack end.

The criteria of Fracture Mechanics are applicable to the macrocrack, the length of which must be set in order to make designs. But macrocrack grows up from the initial dangerous microcrack when the latter reaches so called «critical length l_{cr}», which is unknown. The investigations [27] recommend to find the l_{cr} depending on type and concrete aggregate coarseness d_{max}.

$$l_{cr} = Kd_{\max}, \quad K = \begin{cases} 1.4-2-\text{broken stone (granite, diabase)}, \\ 1.2-1.5-\text{gravel (granite, diabase)}, \\ 1-\text{soft aggregate (limestone)}. \end{cases} \qquad (8)$$

It is clear recommendations (8) are indefinite enough and question about determination of the l_{cr} is retained by the live issue.

4.3. Variational methods of problems solving. At present it is acknowledged [14, 27] that one from most productive methods of Continuum Mechanics problems solving are methods based on the Direct Methods of Variations Calculus and respective Variational Principles. The known in Continuum Mechanics Variational Principles [14, 28] allows to reduce the problem of integration of Differential Equations System to equivalent Variational problem of search of function which give to some integral (functional) the minimum value. For model of rigid-perfect-plastic body the Variational Principles lead to know Theory of Ultimate balance [23, 29] with its two extreme theorems and respective two methods of ultimate load approximate determination: static and cinematic [14, 29].

The cinematic method is considerably more simple and convenient for application than static one and therefore it has far more broad use. The important positive feature of cinematic method is obviousness and explanatory ability of being used cinematic failure schemes which more profound reveal the failure physical reality of considered systems and assist to designers and students to master this method. Therefore in the OSTRCE and the EMPS the cinematic method is solely used.

4.4. Method of sections in theory of cracks. This method was offered as method of approximate determination of stress intensity factor KI [30] and the one allows to simplify considerably the problems solving regarding both ultimate limit and serviceability limit states of RCE and RCS.

CONCLUSIONS

The totalities of present-day designs for RC structures, recommended by the Codes of different countries of the world, possess the considerable demerits the sources of which are insufficient use of the contemporary knowledge of Systemology and Mechanic-Mathematic sciences, including in particular the Theory of Plasticity and Fracture Mechanics. The offered trends to improvement of designs system for RC structures are just connected with the use of noted Sciences. The inexact semi-empiric design models offered in different Codes are presented as care about decrease of calculation cost. But herewith it is forgotten about decrease of optimization ability of such designs. Apparently at present the computers' possibilities jointly with Direct Variation Methods allow to use the precise enough models and simple accessible for designers and students designs. Improvement of designs system can't be realized without profound enough study of mentioned above scientific branches in universities.

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