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Calculation and Design of Buildings (Structures) Taking into Account Seismic Loads According to KMK 2.01.03-19

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ABSTRACT: The present paper analyses the situations that may arise while designing and calculating buildings and structures in accordance with the norms and rules of the KMK 2.01.03.-19 "Construction in seismic zones" and gives proposals for the further correction and improvement of the method of accounting for seismic loads.

I. INTRODUCTION

Within the framework of the implementation of the decree of the President of the Republic of Uzbekistan №P.D.-3190 dated August 9, 2017: “On measures to improve the conduct of scientific research in the field of seismology, earthquake-resistant construction and seismic safety of the population and the territory of the Republic of Uzbekistan”, and P.D. -4794 dated July 30, 2020: "On measures to radically improve the system for ensuring the seismic safety of the population and the territory of the Republic of Uzbekistan", a lot of work has been done, related to the preparation of changes № 1 (2007) and № 2 (2019) [2] to adjust the regulatory framework for the design of buildings and structures KMK 2.01.03-96 "Construction in seismic regions", to ensure the safety of the population and object of industrial and civil construction [1].

II. RELEVANCE AND MAIN OBJECTIVES OF THE PROBLEM.

Instead of KMK 2.01.03-96, KMK 2.01.03-19 was put into operation from March 1, 2020 on the territory of the Republic of Uzbekistan and establishes requirements for the design, construction, strengthening and restoration of new and reconstructed buildings (structures) in areas with seismicity 7, 8, 9 and more than 9 points, taking into account the natural and climatic conditions of the regions. Along with the objects of mass development, the requirements of the KMK apply to new structural systems that have not been considered previously. This is stimulated by a large flow of local and foreign investments aimed at the construction of buildings and structures in rural areas up to 5 floors, and in cities 9-16 and more, in particular, housing construction in the Republic of Uzbekistan [3].

Taking into account these circumstances, it is necessary to continue studying the advantages and disadvantages of the KMK 2.01.03-19 methodology, as well as to continue research on ensuring the seismic safety of industrial and civil construction facilities, which are especially relevant today. The changes in the structure of the KMK were also considered in comparison with the normative documents of the USSR, the CIS and Russia [4, 5].

III. ANALYSIS OF THE CALCULATION RESULTS.

The results of calculations of a building (structure) were analyzed, using the calculation methodology according to KMK 2.01.03-19 [3], according to Code of Recommended Practice 2.7-81 * (USSR) [4] and Set of Rules 14.13330.2014 (Russia) [5] and some shortcomings of the norms that prevent to obtaining the unambiguous results are given.

As an example, a design scheme of a skeleton frame with a span of 6 meters, a single-span 4-storey building (residential, public or industrial, made of reinforced concrete with a height of 12,0 m (the height of each floor is 3,0 m) is adopted. Cross-section of columns and girders is 400x400 mm, concrete of B30 class ($E_b = 33{,}1 \cdot 10^3$ MPa).

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The frame is loaded with 2 load cases: the 1-st load is horizontal dynamic loads (seismic); the 2-nd load - vertical static loads. To create a seismic load according to

To create a seismic load according to KMK 2.01.03-19, the following coefficients were taken α = 1 according to the item 2.16; K_p = 1 is a coefficient of regulatory; K_o = 1 is a coefficient of responsibility; $K_{эт}$ = 1 is a coefficient depending on the number of storeys of the building (structure), determined according to item 2.17; $K_п$ = 1 is a coefficient of accounting for the frequency of earthquakes [3].

Let’s compare the obtained values of this example of seismic loads and efforts in the elements of a 4-storey single-span frame building for a site with seismicity of 9 points, with soils of the 2-nd category in terms of seismic properties and in the period of oscillation of the first tone T_1 = 0,9852 sec (see computer calculation), the weight of the floor of the building referred to the point "K" - Q_K = 500 kN (without taking into account the loads of the main combination): according to the Code of Recommended Practice 2-7-81* (item 2.5-2.10) [4], Set of Rules 14.13330.2014 [5] and according to KMK 2.01.03-19 [3] - according to the limiting state of Limit of State-1, taking into account the requirements of paragraphs 2.22 and 2.24, with a reduction ratio “r”, corresponding to different values of the relative inelastic deformation of elements μ according to table 2.11, and r = 1,0, assuming elastic deformation of structures.

When calculating buildings (structures) according to point 2.6 b, to check the non-occurrence of the limiting state, the calculated forces in the elements of the structural system from a special combination of loads, taking into account seismic forces, are calculated by the formula 2.8 [3]

To take into account the seismic force, the second part of the formula (2.8) [3] is used, deciphered under the radical expression by the authors of the article, which takes into account 4 modes of vibration (see p. 135 [9]):

For columns, when μ = 5 (2.9) the formula r = - 4.27 and conditions (2.10) are not met (r = - 4,27 ≥ r_1 = 1,951, then (2.11) is equal to r = $0,85\mu^{-0,67}$ = 0,289).

For crossbars, when μ = 7,5 (2.9) the formula r = - 4,27 and conditions (2.10) are also not met (r = - 4,27 ≥ r_1 = 1,951, then (2.11) is equal to r = $0,85\mu^{-0,67}$ = 0.222.

According to KMK 2.01.03-19, the following values of the coefficients are taken for formulas (2.3) and (2.4): K_o = 1,0 is a coefficient of responsibility according to table 2.3; $K_п$ = 1,0 is a coefficient of accounting for the recurrence of earthquakes according to table. 2.4;

$K_{эт}$ = 1,0 is a coefficient, depending on the number of storeys and the constructive solution of buildings and structures according to table. 2.10; K_p = 1,0 is a regularity coefficient, according to the table 2.12; K_δ = 1,0 is a coefficient of dissipation according to the formula (2.5), when δ = 0,3 according to the table 2.9; α = 1 at seismicity of 9 points according to table 2.7; W_i = 0,48 when T_1 = 0,9852 sec according to table 2.8; $\eta_{1к}$ = 1,278495, for example, for the first form of natural vibrations. The seismic inertial force under the assumption of elastic deformation of structures (without taking into account the reduction factors) according to (2.3) and (2.4) is determined by the formula –

$$S_{iк} = K_0 \cdot K_п \cdot K_{эт} \cdot K_p \cdot K_\delta \cdot \alpha \cdot Q_к \cdot W_i \cdot \eta_{1к}.$$

According to the Code of Recommended Practice 2-7-81* [4], the following values of the coefficients are accepted to formulas (1) and (2): 3; K_1 = 0,25 is a coefficient, taking into account the permissible damage to buildings and structures is adopted according to table 3; K_2 = 1,0 - coefficient taking into account the constructive solutions of buildings and structures, taken according to table 4; K_ψ = 1,0 - according to table 6; A = 0,4 - at 9 points; β_i = 1,1/T_1 1,1/0,9852 = 1,1165; the coefficient $\eta_{1к}$ = 1,278495, for example, for the first mode of vibration. Then, the seismic inertial force is determined by the formula:

$$S_{iк} = K_1 \cdot K_2 \cdot K_\psi \cdot Q_к \cdot A \cdot \beta_i \cdot \eta_{1к}.$$

According to the Set of Rules 14.13330.2014 [5], the following values of the coefficients to the formulas (1) and (2) are accepted: K_o = 1,0 is a coefficient, taking into account the purpose of the structure and its responsibility according to table 3; K_1 = 0,35 is a coefficient, taking into account the permissible damage to buildings and structures, taken according to table 4 for reinforced concrete framed buildings (when calculating deformations, the value of K_1 = 1,0 - see note 2 to Table 4); K_ψ = 1,3 is a coefficient taking into account the ability of buildings and structures to dissipate energy, according to table 5; A= 4 м/с^2 is acceleration at the base level at 9 points; β_i= $2,5\cdot(0,4/T_1)^{0,5}$ is a dynamic coefficient at T_i > 0,4 sek; the coefficient $\eta_{1к}{}^j$ = 1,278495, for example, for the first form of oscillations. The seismic inertial force is:

$$S_{iк}{}^j = K_o \cdot K_1 \cdot K_\psi \cdot m_к{}^j \cdot A \cdot \beta_i \cdot \eta_{iк}{}^j.$$

Based on the results of the calculations, it was established that the obtained values of the forces from the seismic load in the sections of the elements adjacent to the nodes under the assumption of the elastic deformation of structures according to KMK, Code of Recommended Practice and Set of Rules are in equilibrium.

However, in the KMK, instead of the coefficient K_1, which takes into account the permissible damage of buildings and structures to the entire object, different reduction coefficients r are taken into account (according to the point 2.22 of

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the KMK) for different elements, taken independence on the oscillation period of the first tone T_1 and on the relative inelastic deformation of the elements μ, according to table 2.11. Moreover, different reduction factors are taken to different elements, when determining in them the combinations of forces from seismic loads (taking into account the assumed different responsibility of the elements for the transition of the building to the limiting state), which inevitably leads to a violation of the general principles of structural mechanics, the equilibrium in the sections of the elements adjacent to the nodes is disturbed. For example, set different coefficients μ = 5 for columns and μ = 7,5 for girders, and calculate using the KMC method, then the balance of forces in the sections of elements adjacent to the nodes is immediately violated [7].

If instead of the coefficient $[\mu_k]$ = 5 or 7,5, which is the same for all elements of columns and girders, take into account in the formula (2.3) in the KMK formula an additionally the correction factor K_r = 0,2892 or K_r = 0,22 (equal to r - the reduction factor) when μ = r = 1,0, then the balance in the elements adjacent to the nodes is fulfilled.

But in reality, under a seismic load, defects and cracks appear in the elements, both along the normal and along the inclined section, which leads to a decrease in their rigidity. If in this way we take into account the possibility of reducing the rigidity, first of all, of the girders, then we can consider what will happen when the combinations of forces in the frame elements as a whole. In the example, set the same coefficient for all elements of columns and crossbars of the frame $[\mu_k]$ = 5, but reduce the modulus of elasticity of the girder concrete by the amount equal to the ratio of the girder reduction coefficients to the column reduction factors – $0{,}222/0{,}289 = 0{,}768\cdot(33{,}1\cdot10^3)= 25{,}42\cdot10^3$ MPa, in this way, take into account the assumed different responsibility of the elements for the transition of the building to the limiting state, then the balance of efforts in the elements adjacent to the nodes is carried out, but in this case, the efforts and combinations of forces in the sections of the considered elements and displacements in the nodes will also change. But something else is also important. A change in the stiffness of the girders leads to a change in the forces and combinations of forces in the considered sections of the elements and in the presence of a full load including the loads of the main combination, which is not taken into account by the KMK method. In general, there is a redistribution of efforts in the frame system with maintaining the balance of efforts in the nodes. The resulting combinations of forces can be used in the selection of cross-sections of elements. Thus, you can see that when the stiffness of the girders is changed, a redistribution of forces occurs, which does not correspond to the standard method used in the KMK [1, 3, 7, 8].

Combinations of KMK efforts were determined for several options:

- according to the existing standard methodology, with the coefficients μ and r of the frame elements, corresponding to different responsibilities in the formula (2.8);
- at the coefficients μ and r corresponding to the same responsibility for all elements of the frame of the elements in the formula (2.8), separately, when μ = 5 and μ= 7,5;
- according to the proposed approach to the methodology of the variants were considered for setting the coefficient μ = r = 1 according to the formula (2.8), while simultaneously setting a correction coefficient equal to K_r in formulas (2.4), corresponding to different responsibilities of all frame elements, but separately for more and less responsible elements (when re-calculating).
- options were also considered for specifying in columns and girders sections of the reduced stiffness along the length of (1,5...2)h, where h = 400 mm is the cross-section size of the girder or the column, by reducing the modulus of elasticity is proportionally to the reduction of the reduction coefficients in the sections of the elements, adjacent to the nodes, separately in the girders, columns and simultaneously in the columns and girders.

IV. RESEARCH RESULTS.

It was found, that when simultaneously setting different values of μ for elements with different responsibilities according to the KMK method, the combination of forces in the considered sections of the elements adjacent to the nodes are unbalanced, for example, in the upper node in the column in section 4-2, M = ±97,34 kN·m, and in the adjoining girder in section 12-1, M = ±74,19 kN·m. In the case of setting the same values of μ for all elements during re-calculation (separately for elements with greater responsibility and with less responsibility), the combination of efforts in the considered sections of elements adjacent to the nodes are balanced, similar to the results, but these results must be analyzed separately for girders and separately for the columns.

When calculating according to the proposed approach to the KMK method, while using the coefficient K_r = 0,2892 (which corresponds to μ = 5) in formula (3) and taking the same values of μ = r = 1 for all elements in the formula (2.8), the combination of forces in of the considered sections of the elements adjacent to the nodes are obtained balanced, for example, in the upper node in the column in section 4-2, M = ±97,34 kN·m, and in the adjoining girder in section 12-1,

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M = ±97,34 kN·m, but it is also necessary to analyze these results separately for the girders and separately for the columns, setting the required values of the K_r coefficient separately for columns and girders when recalculating.

When analyzing options for specifying sections of reduced stiffness in columns and girders along the length of (1,5...2)h, where h = 400 mm is the cross-section size of a girder or a column, by reducing the elastic modulus in proportion to a reduction in the reduction coefficients in the sections of the elements adjacent to the nodes, separately in the girders of the columns, and simultaneously in the columns and girders, that in all cases there is a redistribution of combination of efforts. But in the sections of the elements, adjacent to the nodes, the combination of efforts remain in equilibrium. So, with a slight decrease in the rigidity of the cross-bars, the bending moments in the columns practically did not change in comparison with the calculation data according to the KMK method and the moments in the girders even increased (bur did not decrease), compared with the results of the calculations by the KMK method, and the displacements of the frame and skews of the floor along the elastic stage increased slightly, amounting to 153,44 mm > 147,76 mm. With the further decrease in the rigidity of the sections of girders and columns, the combinations of forces in the girders and columns sharply decrease, while remaining balanced in the nodes, but at the same time, the displacements of the frame and the skews of the floors increase sharply amounting to 234,9 mm, and the periods of oscillation. Longitudinal and lateral forces are redistributed similarly.

It is interesting to note, that when comparing the calculation results, according to Russian standards, there was a significant increase in the combination of forces in the frame elements, calculated according to the Set of Rules 14.13330-2014 [5], the displacements of the top of the frame in the elastic stage are equal to 255,33 mm, significantly more than according to the Code of Recommended Practice 2.7-81* [4] and with KMK 2.01.03-19 [3].

V. CONCLUSION

Despite a significant number of studies, the relevance of this issue requires continuation of research of the design and inspection of the technical condition of buildings (structures), taking into account the seismic effects according to KMK 2.01.03-19 from the point of view of efficiency and reliability (seismic safety, durability):

1. The standard method used for determining seismic loads and combinations of forces in sections of elements of buildings and structures, taking into account the different degrees of responsibility of elements for the transition of buildings (structures) to the limiting state, along with savings, can lead to a decrease in the reliability of some types of buildings and structures (especially those with long periods of natural oscillations), in comparison with those, when they are calculated according to the norms of other countries, for example, the CIS, Russia, Ukraine, Kazakhstan and others.

2. This technique is used, when [μ] and r is set for all elements, taking into account the reduced rigidity in individual elements, for example, a decrease in their elastic modulus (taking into account the assumed different responsibility of the elements for the transition of the building to the limiting state), makes it possible to take into account the redistribution of efforts, when defects appear in any elements, to obtain results similar to the KMC method and allows you to get rid of its main drawback - the lack of balance of combinations of forces in the considered sections of elements adjacent to the nodes [7, 8, 9].

The interest in this issue is also explained by the fact, that theoretical problems were solved in a linear statement. Therefore, a more complete accounting of the actual behavior of buildings and the properties of the structural material, especially in construction areas with a seismicity of 8 and 9 points under the action of seismic loads, allows not only to increase the credibility and reliability of calculations, as well as the efficiency of construction, but also represents an independent scientific interest from the point of view of ensuring earthquake-resistance construction and seismic safety of the population of the Republic of Uzbekistan.

REFERENCES

1. KMK 2.01.03-96. Construction in seismic areas / Goskomarkhitekstroy. Republic of Uzbekistan. - Tashkent, 1996. –127 p.p. (uzbek - 1...87 p.p.; russian - 89...175 p.p.).

2. Change №2 to KMK 2.03.01-96 "Construction in seismic areas" with an explanatory note [Text] / Sh.A. Khakimov, A. A. Nugmanov, B. B. Khaitbaev, B. S. Nurtayev, Sh. T. Abdukamilov, M. N. Ubaydulloyev, G.S.Strigo. Scientific research, design and survey Institute of housing and civil construction J.S.C. "TOSHUYJOYLITI", Tashkent, 2019.- 48 p.p.

3. KMK 2.01.03-19. Construction in seismic areas / Ministry of Construction of the Republic of Uzbekistan. - Tashkent, 2019. –223 p.p. (uzbek - 3...123 p.p.; russian - 124 ... 228 p.p.).

4. Code of Recommended Practice 2-7-81*. Construction in seismic areas. - Moscow: Stroyizdat, 1982.- 48 p.p.

5. Set of Rules 14.13330.2014. Construction in seismic areas (to C of RP-7-81*) / Ministry of Construction of Russia. - Moscow, 2014.- 131 p.p.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 8, Issue 12 , December 2021

6. Ubaydulloev M.N. On the issue of calculating buildings and structures taking into account seismic loads according to the norms of Uzbekistan KMK 2.01.03-96 [Text] / M.N. Ubaydulloyev, G.S. Strigo, N.G. Sayfulova // Scientific and technical journal "Problems of architecture and construction", №2 / 2007, Samarkand, 2007. - 13...16 p.p.

7. Explanatory note based on the results of the analysis of KMK 2.01.03-96 "Construction in seismic areas", with proposals for adjustments [Text] / G. S. Strigo, N.G. Sayfulova, M.N. Ubaydulloyev, O. Ubaydulloyev // LLC "NinaStroyServis" at the region of architecture. - Samarkand State Architectural and Civil Engineering Institute, Samarkand, 2012. - 52 p.p.

8. Ubaydulloyev M.N. Analysis of the state and proposals for adjusting the norms of Uzbekistan KMK 2.01.03-96, when designing buildings and structures, taking into account seismic loads [Text] / M.N. Ubaydulloyev, O. Ubaydulloyev, N. Ubaydulloyeva // Scientific and technical journal. "Problems of architecture and construction", №2 / 2018, Samarkand, 2018. - 33 ... 36 p.p.

9. Ubaydulloyev M.N. A practical approach to the calculation and design of buildings (structures), taking into account seismic loads, according to the norms of Uzbekistan KMK 2.01.03-19 [Text] / M.N. Ubaydulloyev, O. Ubaydulloyev, N. Ubaydulloyeva // Scientific and technical journal. "Problems of architecture and construction", №4 / 2020, Samarkand, 2020. - 134 ... 138 p.p.