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КЫРГЫЗ РЕСПУБЛИКАСЫНДА КУРУЛУШ АЯНТЫНЫН СЕЙСМИКАЛЫК КООПТУГУН ЖАНА ИМАРАТТАРДЫН КОНСТРУКЦИЯЛАРЫНЫН КӨТӨРҮҮ ЖӨНДӨМДҮҮЛҮГҮН АНЫКТООНУН ЫКМАЛАРЫ

Абдыкалыков А.А.[1], Абдыбалиев М.К.[2], Бегалиев У.Т.[3]
[1]*Н. Исанов ат. Кыргыз мамлекеттик курулуш, транспорт жана архитектура университети, abdykalykov57@mail.ru*
[2]*ААК «Промпроект», maratprom@mail.ru*
[3]*Эларалык сейсмотуруштуу курулуш боюнча эксперттердин ассоциациясы, Эларалык инновациялык технологиялар университети, utbegaliev@mail.ru*

Аннотация: *Документте Кыргыз Республикасы үчүн жакында жаңыланган СН КР 20-02:2018 сейсмикалык долбоорлоо жоболоруна киргизилген өзгөчөлүктөрү талкууланат. Негизги жоболор имараттарга жана курулмаларга долбоордук сейсмикалык аракеттерди жана жүктөрдү аныктоого, ошондой эле пландагы жана бийиктиктеги имараттардын конфигурациясынын бузууларын текшерүүгө байланыштуу. Кыргыз Республикасынын аймагы үчүн сейсмикалык коркунуч бул сейсмикалык жоболору менен мүнөздөлөт, алар детерминисттик негизге ээ болгон татаал сейсмикалык коркунуч карталары бар. Карталарда жер титирөөнүн ар кандай жерлер үчүн интенсивдүүлүгү жана тоо тектеринин геологиялык түзүлүштөрүнө жараша жер титирөөнүн эң жогорку ылдамдыгы жөнүндө маалыматтар камтылган. Курулуш аянтындагы сейсмикалык аракеттер ылдамдануу реакциясынын спектри менен мүнөздөлөт. Курулуш объектилери үчүн долбоордук сейсмикалык күчтөр алардын маанилүүлүгүн, пландагы жана бийиктиктеги конфигурациясынын мыйзамдуулугун, ошондой эле бурулууга туруктуулугун эске алуу менен аныкталат. Бул кодекстерге ылайык, имараттар маанилүүлүгүнө, жайгаштырылышына жана кабаттарынын санына жараша класстарга бөлүнөт. Имараттардын маанилик класстарынын жана кабаттардын санынын ар бир айкалышы үчүн сейсмикалык долбоордук жүктөрдү аныктоодо эске алынуучу белгилүү бир маанилүүлүк коэффициенти ыйгарылат. Имараттардын конструктивдик схемалары планда же бийиктиги боюнча азыраак регулярдуу эмес жана ашыкча регулярдуу эмес деп классификацияланат.*

Ачкыч сөздөр: *сейсмикалык реакция, сейсмикалык коркунуч картасы, жер титирөөнүн интенсивдүүлүгү, жер үстүндөгү пиктик ылдамдануу.*

ПОДХОДЫ К ОПРЕДЕЛЕНИЮ СЕЙСМИЧЕСКОЙ ОПАСНОСТИ СТРОИТЕЛЬНОЙ ПЛОЩАДКИ И НЕСУЩЕЙ СПОСОБНОСТИ КОНСТРУКЦИЙ ЗДАНИЙ В КЫРГЫЗСКОЙ РЕСПУБЛИКЕ

Абдыкалыков А.А.[1], Абдыбалиев М.К.[2], Бегалиев У.Т.[3]
[1]*Кыргызский государственный университет строительства, транспорта и архитектуры им. Н.Исанова, abdykalykov57@mail.ru*
[2]*ОАО «Промпроект», maratprom@mail.ru*
[3]*Международная ассоциация экспертов по сейсмостойкому строительству, Международный университет инновационных технологий, utbegaliev@mail.ru*

Аннотация: *В статье рассматриваются особенности недавно обновленных норм проектирования в сейсмостойком строительстве СН КР 20-02:2018 для Кыргызской Республики. Основные положения связаны с определением расчетных сейсмических воздействий и нагрузок на здания и сооружения, а также с проверкой регулярностей конфигурации здания в плане и по высоте. Сейсмическая опасность для территории Кыргызской Республики характеризуется данными в нормах по сейсмостойкому строительству и картами сейсмической*

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опасности, которые имеют детерминированную основу. Карты содержат информацию об интенсивности землетрясений для различных мест и соответствующих пиковых ускорениях грунта в зависимости от геологических образований горных пород. Сейсмические воздействия на строительной площадке характеризуются спектром реакции ускорения. Расчетные сейсмические нагрузки на проектируемые сооружения определяются с учетом их значимости, регулярности их расположения в плане и высоте, а также сопротивления кручению. В соответствии с этими нормами здания подразделяются на классы в зависимости от их ответственности по назначению и этажности. Каждому сочетанию классов ответственности здания и этажности присваивается определенный коэффициент ответственности, который учитывается при определении расчетных сейсмических нагрузок. Конструктивные схемы зданий классифицированы на регулярные, умеренно нерегулярные и чрезмерно нерегулярные в плане или по высоте.

Ключевые слова: *сейсмическая реакция, карта сейсмической опасности, интенсивность землетрясений, пиковые ускорения грунта.*

APPROACHES TO DETERMINATION OF SEISMIC HAZARD ON BUILDING AREA AND DEMAND FOR BUILDING STRUCTURES IN THE KYRGYZ REPUBLIC

Abdykalykov A.A.[1], Abdybaliev M.K.[2], Begaliev U.T.[3]

[1]*Kyrgyz State University of Construction, Transport and Architecture after named N. Isanov, abdykalykov57@mail.ru*

[2]*Design Institute JSC "Promproject", Bishkek, Kyrgyz Republic, maratprom@mail.ru*

[3]*International Association of Experts on Earthquake Engineering, International University of Innovation Technologies, Bishkek, Kyrgyz Republic, utbegaliev@mail.ru*

Abstract: *The paper discusses specific features of the recently updated seismic design code SN KR 20-02:2018 for the Kyrgyz Republic. The key provisions are related to the determination of design seismic actions and loads on buildings and structures, as well as checking irregularities of building configuration in plan and elevation. Seismic hazard for the territory of the Kyrgyz Republic is characterized by these seismic code with complex seismic hazard maps, which have a deterministic basis. The maps contain information about earthquake intensity for various locations, and the corresponding peak ground accelerations depending on the rock geological formations. Seismic actions at a construction site are characterized by an acceleration response spectrum. The design seismic loads for the designed facilities are determined taking into account their importance, regularity of their configuration in plan and elevation, as well as torsional resistance. According to these codes, buildings are classified into classes depending on their importance, occupancy, and the number of storeys. Each combination of building importance classes and number of storeys is assigned a specific importance coefficient which is taken into account in determining the design seismic loads. Structural configurations are classified by regularity in plan and elevation into regular, moderately regular and excessively irregular.*

Keywords: *seismic response, seismic hazard map, earthquake intensity, peak ground accelerations*

1. Introduction

In almost all CIS-countries, the source of the codes were the standards that adopted and worked precisely during the USSR period. Since independence, each country began to approach in its own way, develop separate standards, include its own coefficients, methods. Therefore, our standards vary slightly, but basic requirements remain similar.

For example, Russian seismic codes basically is staying on last level and basis on new seismic hazard complex maps with probabilistic basis for Russian Federation with 10%, 5% and 1% with probabilistic for 50 years. The indicated probability values correspond to the

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average time intervals between earthquakes of the calculated intensity: 500 years (map A), 1000 years (map B), 5000 years (map C).

Kyrgyz Republic (KR) located in Central Asia and has the territories with high seismic hazard. Central Asia's earthquake activity has long been recognized as one of the highest in the world. A significant portion of the KR terrirory is expected to be exposed to earthquakes of magnitude 7.5 or higher per Richter scale (corresponding to the shaking intensity 9 per MSK-64 scale). The territory of the KR was subjected to several damaging earthquakes, including the 1992 Sysamyr earthquake (magnitude 7.3). In the period from June 1, 2009 to Sept. 30, 2010, the country experienced 2,398 earthquakes of magnitude 6 or higher. The seismic codes for the country were developed on the basis of seismic hazard maps, which have a deterministic basis.

The paper discusses some peculiarities of the Building Code KR 20-02:2018 related to the determination of design seismic actions and loads on buildings and structures, as well as checking their regularity in plan and height.

2. Peculiarities on determining of the seismic hazard area and construction site

Seismic hazard for the territory of the KR is characterized by the code 20-02:2018 through seismic hazard maps which were developed and approved by the Institute of Seismology of the National Academy of Sciences of the KR, by Abdrahmatov et all (2018). The following maps are included in the Code:

1) map of maximum local magnitude (MLH) distribution of active seismic faults and their segments, which generate earthquakes in the KR;

2) map of peak ground accelerations in rock soils (Fig. 1) for the horizontal component of seismic vibrations within the KR’s territory (seismic-risk zoning map), and

3) map showing intensities of earthquake vibrations for probable maximum earthquakes in the KR.

The above-mentioned maps are supplemented by a list of settlements within the KR and the corresponding seismic hazard parameters, both in terms of the intensity and peak ground accelerations, Brzev and Begaliev (2018).

The design value of the horizontal peak ground acceleration for a construction site a_g takes into account its actual soil (ground) and topographical conditions, and it is defined from the following expression:

$$a_{\mathrm{g}} = a_{\mathrm{gR}} \times S(a_{\mathrm{gR}}) \times S_{\mathrm{T}} \quad (1)$$

where:

a_{gR} – reference value of horizontal peak ground acceleration (as a fraction of g) for the considered construction site under soils type IA (rock soil), determined based on map of peak ground accelerations and/or based on list of settlements; $S(a_{gR})$ – a coefficient which takes

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into account the effect of the actual soil conditions of the construction site on the intensity of seismic impacts (actions) defined in accordance with Table 1; S_T – a coefficient that takes into account the topographical effects of increasing horizontal seismic actions at the construction site.

Table 1. Values of the S(a_{gR}) coefficients in Kyrgyz code

Types of soil conditions by seismic properties (shear wave velocity in surface soil columns)	KR Code: Value of $S(a_{gR})$ coefficient depending on a_{gR} value
IA – Rock soils ($v_{s,30}$≥800 m/sec.)	1,0
IB – Coarse clastic soils - mainly from igneous rocks content more than 70% ($v_{s,10}$≥350 m/sec, 550≤$v_{s,30}$<800 m/sec)	1,0≤(1,4- a_{gR}/g)≤1,2
II – Coarse clastic soils of all types - with aggregate content more than 30% (230≤$v_{s,10}$<350 m/sec, 270≤$v_{s,30}$<550 m/sec)	1,1≤(2,0 - 2,5 * a_{gR}/g)≤1,6
III – Friable sands, coarse and mean size water saturated ($v_{s,10}$<230 m/sec, $v_{s,30}$<270 m/sec)	1,3≤(2,5 – 3,0 * a_{gR}/g)≤2,4

The design seismic actions at a construction site are characterized by response spectra and peak ground accelerations.

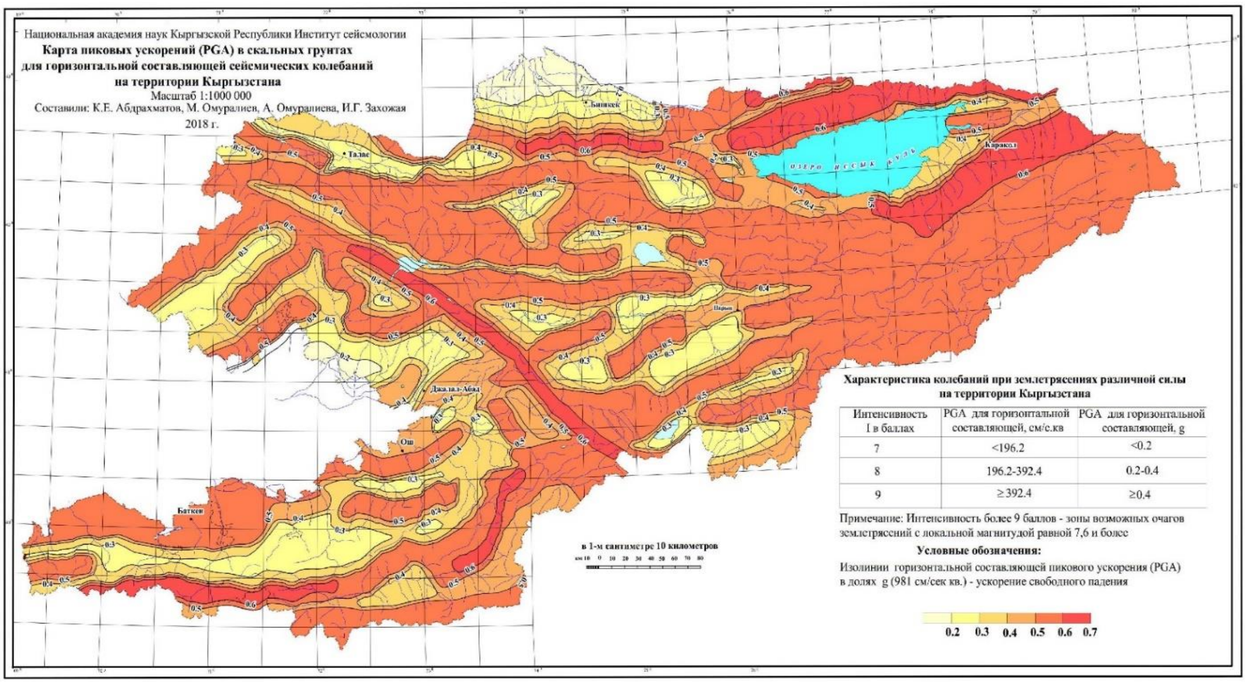

Fig. 1 – Map of peak ground accelerations in rock soils for the horizontal component of seismic vibrations within the KR's territory (seismic-risk zoning map)

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For the horizontal components of seismic action, the design response spectrum S_d(T) should be determined from expressions (2) and (3):

$$0 \le T \le T_C: \qquad S_d(T) = a_g \cdot \frac{2{,}5}{q} \qquad (2)$$

$$T \ge T_C: \qquad S_d(T) = a_g \cdot \frac{2{,}5}{q} \cdot \left[\frac{T_C}{T}\right], \text{ but no less than } \beta \cdot a_g, \qquad (3)$$

where: T_C is the maximum value of period on the constant section of the spectral accelerations graph S_d(T), taken in accordance with the data in Table 2; T is the period of linear oscillations in horizontal direction; q is a behavior coefficient; note that q is an inverse value of the reduction coefficient k_2, adopted in the previous seismic codes: q=1/k_2; β is an indicator of lower limit of the spectrum taken as 0,2.

For the vertical components of seismic action, the design response spectrum S_{dv}(T) should be determined using the expressions (4) and (5):

$$0 \le T_v \le T_{Cv}: \qquad S_{dv}(T) = a_{gv} \cdot \frac{2{,}25}{q} \qquad (4)$$

$$T_{Cv} \le T_v \le 2{,}0: \qquad S_{dv}(T) = a_{gv} \cdot \frac{2{,}25}{q} \cdot \left[\frac{T_{Cv}}{T_v}\right]^k, \qquad (5)$$

where T_{Cv} is the maximum period on a constant segment of spectral acceleration graph S_{dv}(T), taken equal to 0.2 seconds; T_v is a period of linear oscillations in vertical direction; k is an exponent depending on the type of soil, taken in accordance with Table 3; a_{gv} is a design vertical acceleration at the construction site (see Table 4); q_v is a behavior coefficient, whose value should always be taken as 1.5 (see Table 5).

Table 2. Values of T_c periods

Type of soil	T_c (sec)
IA and IB	0,48
II	0,72
III	0,96

Table 3. Values of k

Type of soil	k
IA and IB	0,60
II	0,45
III	0,35

Table 4. Characteristic a_{gv} value depending on a_g

Type of soil	$a_g \le 0{,}12g$	$0{,}12g \le a_g \le 0{,}4g$	$a_g \ge 0{,}4g$
IA, IB, II and III	0,7	0,8	0,9

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Table 5. Values of a behaviour coefficient ***q*** *for buildings regular in height*

Type of structural system for buildings	*q*
1 Buildings for which structural damages or inelastic deformations are not allowed.	1.0
2 Buildings with loadbearing walls of cast reinforced concrete, large panel, volumetric-block: a) cross-wall structural systems with external and internal bearing walls located at spacing not exceeding 6 m, and slabs resting on four sides of the walls;	5.0
b) cross-wall structural systems with one loadbearing wall in each main direction; c) other wall structural systems.	3.3 4.0
3 Frame buildings (except as specified in 7 and 8): a) with spatial channel frames having all rigid joints of columns and crossbars; with frame-bonded skeletons having all rigid joints of columns and crossbars; with bonded frames, frame-wall structural systems; one-story frames of all structural systems, except for those specified in b); b) other structural systems, except as indicated in a).	4.0 3.3
4 Buildings with monolithic masonry walls	3.5
5 Buildings with loadbearing walls of brick (masonry) work of composite structure.	3.3
6 Buildings with loadbearing walls of reinforced brick masonry with seismic safety measures	3.0
7 Torsionally-pliable structural systems	2.0
8 Structural systems of “inverted pendulum” type	1.5
9 Wooden buildings in the form of: a) statically indeterminate portal frames with connections on pins or bolts; b) wall panels joined with nails and bolts;	3.0 4.0
10 Buildings with loadbearing walls of local construction materials (adobe and similar). Buildings with loadbearing walls of unreinforced brick masonry without seismic safety measures.	To be determined based on the results of a special survey
Type of Engineered Structures	
1. Structures including free-standing towers, chimneys and masts: a) with loadbearing reinforced concrete or steel structures behaving as unbraced consoles for more than half of their total height; b) with reinforced concrete or steel structures behaving as a cantilever console for less than half of their full height or fixed by guy lines in the level of the center of the structural weight or above this level c) brick masonry structure.	2.5 3.5 2.5
2. Structures in the form of single pillars and towers serving as supports for reservoirs and tanks located at their top levels.	1.5
3. Structures of silage towers and elevators.	3.5
4. Structures in the form of frame skeleton towers without infill	3.0
5. Torsionally pliable structures.	2.0
6. Other structures (not specified in 1-5).	3.0

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3. Code provisions related to the design seismic loads and actions on buildings

The design seismic loads for buildings are determined taking into account the importance of these facilities, the regularity of their structural layouts in terms of plan and height, as well as torsional resistance in plan. In the SN KR 20-02:2018 (2018), buildings are divided by importance: a) depending on the functional purpose (into 4 classes), and b) depending on the number of storeys (into 5 classes). Each combination of building importance classes and number of storeys in the SN KR 20-02:2018 are assigned corresponding values of importance coefficients which are taken into account in determining the design seismic loads, Itskov (2018).

Structural schemes are classified in the building code by regularity in plan and elevation into three types as regular, moderately regular, and excessively irregular, while in terms of torsional resistance structural schemes are classified into schemes that possess adequate torsional stiffness, and torsionally-pliable schemes. The adopted classification system is based on the combination of features, which characterize structural systems both qualitatively and quantitatively:

- by peculiarities of configurations in plan and/or elevation;
- by balancing the distribution of mass and stiffness in plan;
- by peculiarities of the distribution of mass and stiffness in elevation;
- by the capacity of the slabs to perform the functions of horizontal stiffening diaphragms.

The classification of structural systems according to regularity in terms of plan and elevation, and torsional resistance is important for the structural and seismic design aspects associated with the selection of the following seismic design parameters:

- coefficient f_{vk} which increases the effects of design seismic actions in the structure at storeys which due to a sharp increase in mass or decrease in stiffness, violate the uniformity of the structural scheme in elevation;
- random eccentricity e_{ak}, which must be taken into account when determining the building torsion effects in plan, caused by spatial variations of the seismic movement, uncertainties in the location of the masses and the consequences of various nonlinear effects;
- behavior coefficient q for torsionally-pliable structural systems in plan, which are defined as systems in which the first mode shape is torsional, and also for excessively irregular structural systems.

In the process of performing calculations, structural and seismic analysis of buildings and structures, taking into account their interaction with the subgrade and/or basement soil, the parameters of equivalent elastic soil stiffness are allowed to be determined using:

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1) experimental data on the velocity of distribution of elastic waves in the soil layers below the base of the foundations;

2) correlation of empirical relationships for the physical and mechanical soil properties under static loads with the velocity distribution of elastic waves through soil layers. When taking into account interaction of a building or structure with the basement soil, the following recommendations are provided:

a) as the base parameter of the equivalent elastic soil stiffness, increase the value of its modulus of deformation determined by the results of static tests 10 times;

b) consider two numerical design models for the same structure: a model in which the base equivalent stiffness of the foundation soil should be increased 1,5 times, and in the other in which it is reduced 1,5 times.

c) adopt the highest values of seismic effects obtained from the numerical design models discussed under b). It should be noted that the seismic hazard assessment for construction sites in slopes are not taken into account when determining the design seismic actions, but are taken into account when prescribing structural measures to be applied regardless of the analysis results for the designed structures.

3. Conclusion

The approaches to define of seismic hazard and seismic demand for building design is changed exactly according of the building codes of EU.

In recent years the requirements of the seismic and/or building codes of the Kyrgyz Republic, governing and regulating the structural and seismic design in seismic areas and the seismic resistance assessment of existing buildings in the KR have undergone significant changes.

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