Строительство уникальных зданий и сооружений. ISSN 2304-6295. 9 (24). 2014. 106-115

Construction of Unique Buildings and Structures

journal homepage: www.unistroy.spb.ru

Investigation of the effect of the quality of concrete mixes on dynamic behavior and seismic resistance of buildings, in experience of Albania

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ARTICLE INFO

Original research article

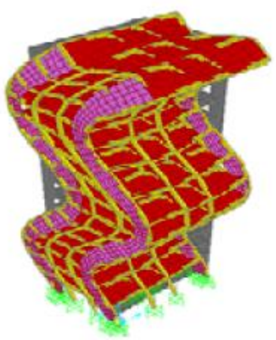
Article history

Received 6 September 2014
Accepted 23 September 2014

Keywords

seismic resistance,
concrete,
strength,
concrete mix,
RC building

ABSTRACT



The paper provides a brief presentation of laboratory investigations of concrete and its components that have so far been performed at the Albanian Construction Institute in Tirana and reflect the Albanian construction practice. Selected results from compressive tests of three concrete mix proportion, (normal, intermediate and high strength) prepared with five different types of cements are presented. In order to study the influence of different concrete classes on dynamic behavior and seismic resistance of buildings, analytical investigations of the seismic response of models of RC buildings have been carried out.

Contents

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1 Introduction

Concrete, in the broadest sense, is any product or mass made by the use of a cementing medium. Generally, this medium is the product of reaction between hydraulic cement and water. But, these days, even such a definition would cover a wide range of products: concrete is made with several types of cement and also containing pozzolan, fly ash, blast-furnace slag, micro-silica, additives, recycled concrete aggregate, admixtures, polymers, fibers, and so on; and these concretes can be heated, steam-cured, autoclaved, vacuum-treated, hydraulically pressured, shock-vibrated, extruded, and sprayed.

Within the frame of this paper an overview of Albanian construction practice regarding achieved quality of the concrete and its constituent components is presented. The aim of the study is also to highlight the considerations that are important when estimating the quality of concrete and cement tested on different samples taken from different regions in Albania and applying different handling procedures and quality of workmanship. All information and measurements necessary for realization of this thesis are taken from the database of the Albanian Construction Institute in Tirana. The other important objective highlight in the paper is study of the influence of different concrete classes to dynamic behavior and seismic performance of buildings [1-22].

2. Laboratory investigations of concrete constituent materials and concrete mixtures

2.1 Laboratory investigations of cement

Laboratory investigations and comparison of the test results regarding compressive and flexural strengths of four different groups of cement samples are carried out. Selected results regarding differences in compressive and flexural strength of cement samples as a function of duration of curing are presented in figures 1 and 2, respectively.

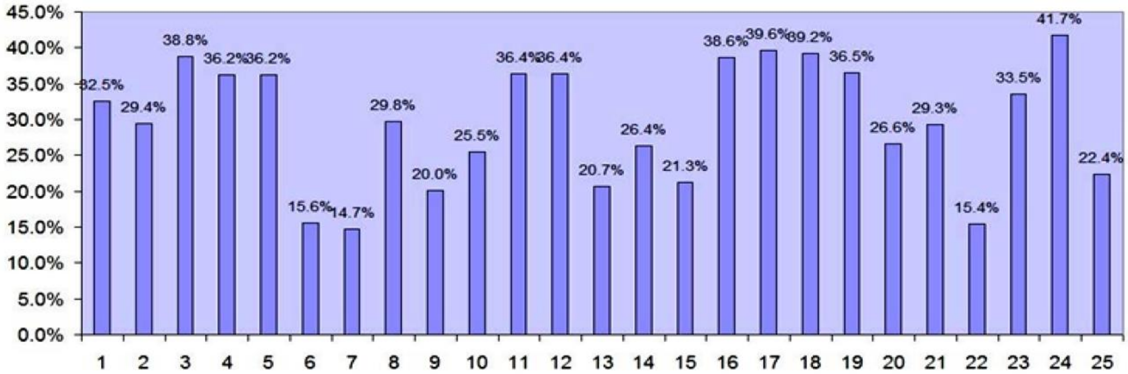

Figure 1. Differences in compressive strength of cement samples_2 after 7 and 28 days of curing

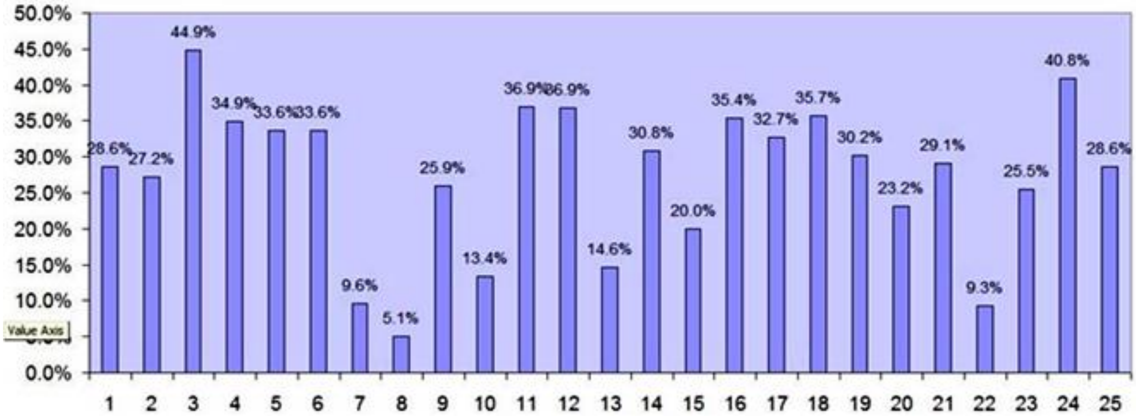

Figure 2. Differences in flexural strength of cement samples_4 after 7 and 28 days of curing

2.2. Laboratory investigations of concrete samples.

2.2.1. Laboratory investigations of aggregates and results from testing

Two main types of aggregates named “Agg.1” and “Agg.2” are used in investigations. The companies that sell these type of aggregates operate in the region of Erzen river, in the central Albania. “Agg.1” type with a maximum aggregate size of 12.5mm is used for production of high strength concrete. The coarse aggregate, “Agg.2” type has sizes of 25mm and it is used for production of normal strength, as well as so called intermediate strength concrete, (figure 3).

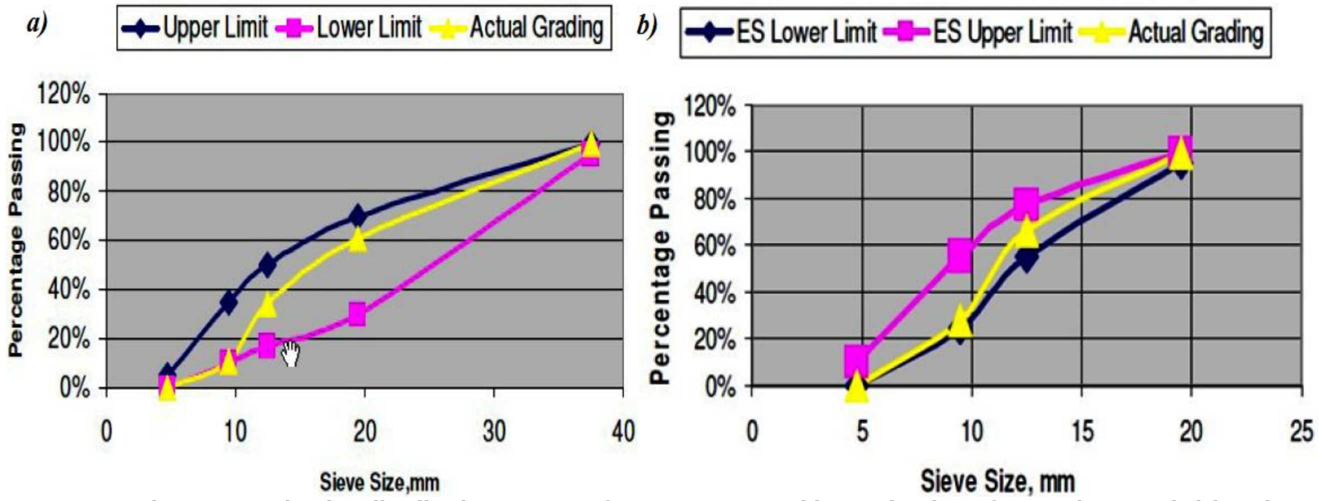

Figure 3. Grain size distribution curves of aggregates used in production of normal strength (a) and intermediate strength (b) concrete
a) Maxumim grain size 25mm, b) Maxumim grain size 19mm

2.2.2. Laboratory investigations of aggregates and results from testing

Results from the laboratory investigations of three concrete mix proportion, (normal, intermediate and high strength) prepared with five different types of cements, cem1 OPC, cem1 PPC, cem2 OPC, cem2 PPC and cem3 PPC, (OPC–"ordinary Portland cement"; PPC–"Portland pozzolana cement) are given. These cements are produced in the Albanian cement factories or imported and sold in Albania, (figure 4).

Code no.	Cement [kg/m3]	Cement type	W/C	water [kg/m3]	Fine Aggr. [kg/m^3]	Coarse Aggr. kg/m^3]	Slump [mm]	Admix. [lit/m3]
							- normal strength -	
A1	370	cem1 PPC	0.5	185	620	1265	35	-
A2	370	cem3 PPC	0.5	185	620	1265	36	-
A3	370	cem2 PPC	0.5	185	620	1265	43	-
A4	370	cem1 OPC	0.5	185	620	1265	43	-
A5	370	cem2 OPC	0.5	185	620	1265	45	-
						- intermediate strength –		
B1	440	cem1 PPC	0.4	180	534	1306	66.4	6.74
B2	440	cem3 PPC	0.4	180	534	1306	81	6.74
B3	440	cem2 PPC	0.4	180	534	1306	69	6.74
B4	440	cem2 OPC	0.4	180	534	1306	94	6.74
B5	440	cem3 OPC	0.4	180	534	1306	141	6.74
							- high strength –	
C1	550	cem1 PPC	0.27	148.4	450	1344	61	16.4
C2	550	cem3 PPC	0.27	148.4	450	1344	71	16.4
C3	550	cem2 PPC	0.27	148.4	450	1344	45	16.4
C4	550	cem1 OPC	0.27	148.4	450	1344	54	16.4
C5	550	cem2 OPC	0.27	148.4	450	1344	34	16.4

Figure 4. Design mixes and slumps for concrete

The rate of compressive strength gain for three concrete groups with normal, intermediate and high strength, prepared with five different cements types and cured in different conditions are presented in figure 5.

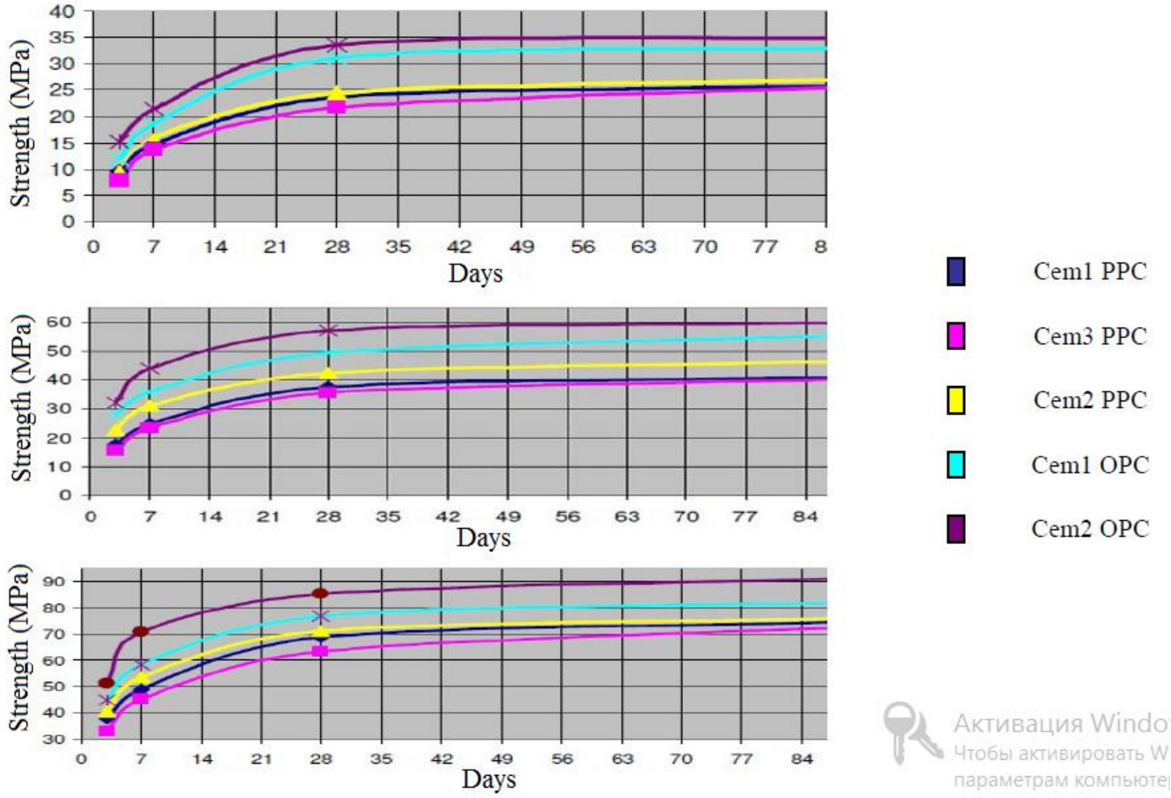

Figure 5. Rate of compressive strength gain for concrete samples produced with different types of cement

From the realized laboratory investigations that following conclusions can be drawn:

- at all ages and classes of concrete, cem2 OPC has produced the highest compressive strength concrete, followed by cem1 OPC, cem2 PPC, cem1 PPC and cem3 PPC.
- for higher early age strength development, both fineness and the percentage of C3S are important parameters. But at later ages, fineness has no effect on strength; besides, due to short moist curing, the contribution of C2S in ultimate strength may not be that much significant. Therefore, it is the high C3S content that gives concrete made of cem2 OPC the highest strength at all ages.
- at the 91 days strength, the significant difference in strength (nearly 10%) is appear between the samples which were water cured for 7 days over the samples which were water cured for 3 days.

3. Seismic performance of RC buildings designed by different concrete classes

In order to achieve the second goal of the paper i.e. influence of different concrete classes to dynamic behavior and seismic resistance of buildings, analytical investigations of the seismic response of three RC building models were carried out, (Necevska-Cvetanovska&Apostolska, 2011). The parametric analyses have been done by variation of the number of storeys of the model; structural system of the model; compressive strength of concrete, i.e., concrete class; proportions of columns; yielding strength of longitudinal reinforcement; and mechanical percentage of reinforcement. For the needs of these investigations, three models of RC buildings constructed of concrete with different compressive strength have been designed in accordance with Albanian code and Eurocode 2&8, (EN 1992-1-1 & EN 1998-1, 2004). In this paper are presented part of the result from model 1 and model 3.

3.1. Design of RC building models for analytical investigations

Model-M1 represents a 7 storey RC frame structure which is symmetrical in both directions. The building has a regular shape at plan (figure 5) with proportions of 25 x 25m and a span between the beams of 5 m. The columns are proportioned 60x60cm at the first three storeys and 50x50cm at the remaining storey. All the beams are designed with proportions 30x50cm, while in the analyses, they have been treated as beams with "T", i.e., "L" cross-section. The floor structure represents an RC plate with a thickness of 20cm. Model-M3 represents a 15 storey RC building with a bearing structural system consisting of frames and walls in both orthogonal directions. The building has a regular shape at plan (fig. 6) and is proportioned 16 x 12m with span of beams in X-direction of 6m, 4m and 6m and 3 spans of 4 m each in Y direction.

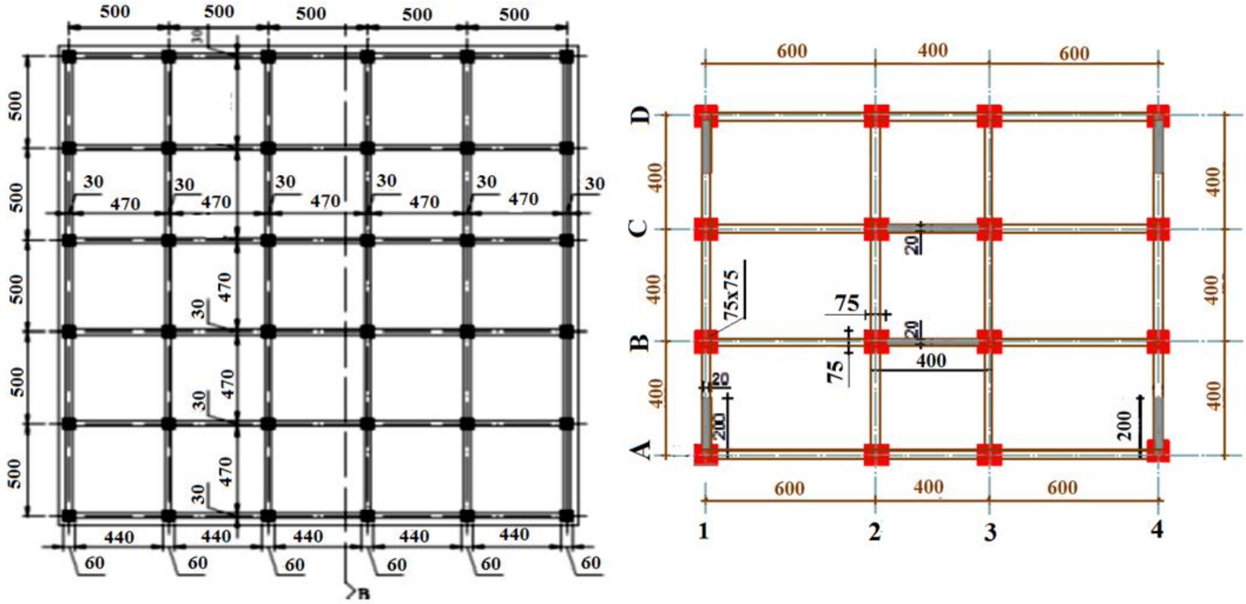

Figure 6. Floor plan of model M1 (left) and M3 (right)

3.2. Static and seismic analysis of the designed RC model buildings and results

The static and seismic analyses of the structural systems of the four designed models have been performed by use of SAP2000v10.0.9Advanced (Wilson&Habibullah, 2006) computer software. The beams and the columns have been modeled by linear finite elements (3D-FRAME elements), while the floor structures and the RC walls have been modeled by 2D finite elements (SHELL elements). The vertical loads have been defined in accordance with the positive technical regulations and the purpose of the structures. The horizontal loads have been defined in the form of design spectra of acceleration in accordance with Eurocode 8 and time history of actual earthquake record (El-Centro).

3.2.1. Model M1

To define the effect of different concrete classes upon natural values and fundamental mode shapes of the structure of model M1, analyses of the model have been made when designed of concrete class C25/30, C50/60 and C90/105. The values of the first and the second mode of vibration are presented in table 2. Model-M2 designed to be constructed of concrete class C25/30 and frame bearing system in two orthogonal directions has been selected as the referent structure. Comparative parametric analyses have been performed to compare the dynamic characteristics and the response of the structure of model – M2 designed with higher concrete classes with the response of the referent structure (table 1).

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Table 1. Effect of concrete class upon period of vibration

	E_b [GPa]`	$f_{b,cube}$ [MPa]	$T_{1,Y}$ [sec]	$T_{2,X}$ [sec]	$T_{3,rot}$ [sec]
C 25/30	31500	30,0	0,96	0,96	0,87
C 50/60	38000	60,0	0,88	0,88	0,79
C 90/105	44320	100.0	0,81	0,81	0,73

The seismic response of model – M1 expressed through the maximum horizontal displacements at the top of the structure and the total shear base force are given in table 2.

Table 2. Maximum values of displacement and shear force

	$f_{b,cube}$[MPa]	b/h [cm]	$\Delta_{X,top}$ [cm]	$\Delta_{all,top}$ [cm]	S_{base} [kN]
C 25/30	30.0	60/60	3,08	3.50	3472
C 50/60	60.0	60/60	2.81	3.50	3831
C 90/105	105.0	60/60	2.58	3.50	4101

3.2.2. Model M3

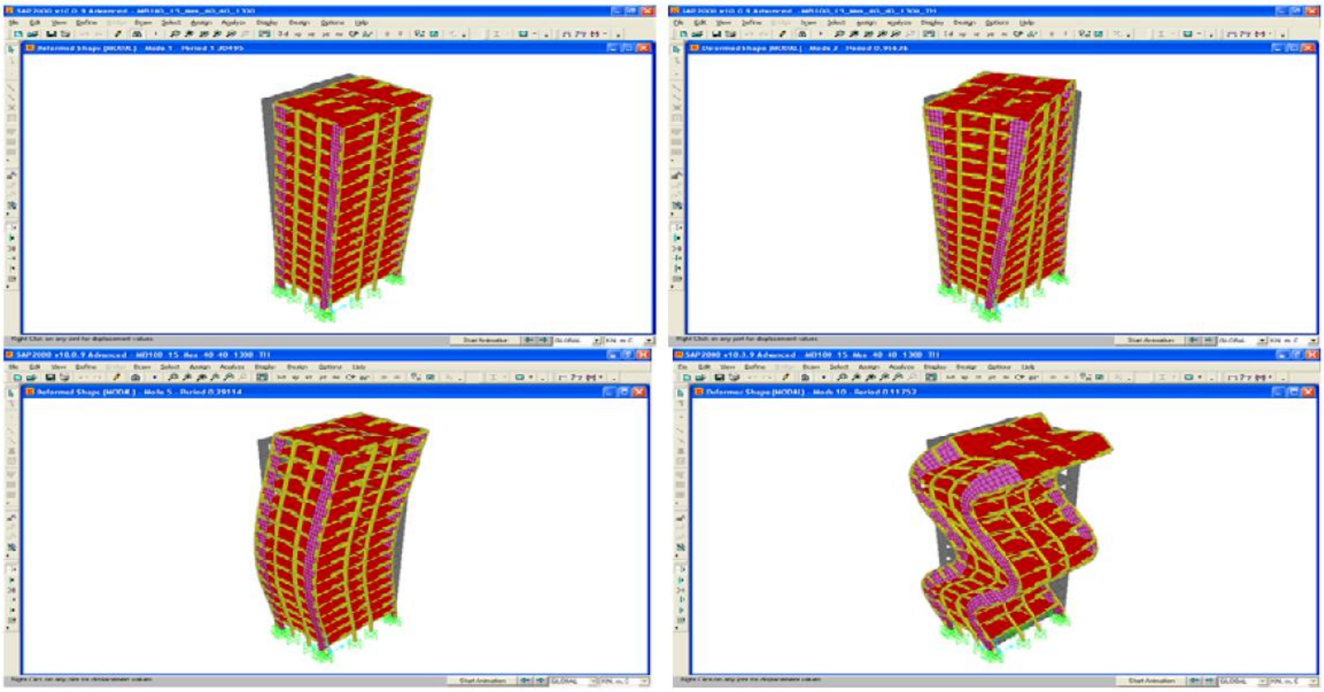

Figure 6. Selected mode shapes of model– M3 designed with C90/105

The dynamic response of the structure of model – M3 designed with C90/105 has been compared with the response of the referent structure for model – M3. The results from the parametric analyses are presented in table 5.

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Table 3. Results from comparative analyses of model – M3

	b/h [cm]	$f_{Y,}$ [MPa]	ρ [%]	K	T_1 [sek]	$\Delta_{Y,top}^{(*)}$ [cm]	$\Delta_{all,top}$ [cm]	S_{base} [kN]	CR
C25/30	75/75	400	1.11	0.218	1.187	4.18	7.50	2576	0.344
C90/105 (1)	40/40	400	3.6	0.218	1.305	4.49	7.50	2168	0.226
C90/105 (2)	40/40	1300	1.11	0.218	1.305	4.45	7.50	2168	0.264

4. Conclusion

Based on the laboratory investigations on achieved concrete quality in Albanian construction practice the following can be concluded:

- at all ages and classes of concrete, cem2 OPC has produced the highest compressive strength concrete, followed by cem1 OPC, cem2 PPC, cem1 PPC and cem3 PPC;
- in general, at later ages of the concrete, the PPCs have shown larger strength increment compared to the OPCs;
- for higher early age strength development, both fineness and the percentage of C3S are important parameters. But at later ages, fineness has no effect on strength.

Regarding influence of different concrete classes to seismic performance of buildings it can be concluded that higher classes lead to decrease of period of vibration and maximum displacements at the top of the structure. It is also notice that efficient use of high strength concrete at the column cross-sections must be coupled with either increased percentage of reinforcement of the cross-section or use of high strength steel.

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Исследование влияния качества бетонных смесей на динамическое поведение и сейсмостойкость зданий, опыт Албании

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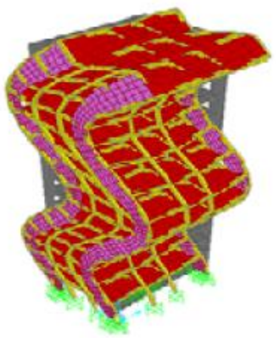
Информация о статье	История	Ключевые слова
УДК 69 Научная статья	Подана в редакцию 6 сентября 2014 Принята 23 сентября 2014	сейсмостойкость, бетон, бетонная смесь, RC моделирование зданий, прочность

АННОТАЦИЯ



В статье представлены результаты аналитических исследований сейсмического отклика моделей RC зданий. Статья содержит краткое изложение лабораторных исследований бетонов и их компонентов для изучения влияния на динамическое поведение и сейсмостойкость зданий. Испытания выполнены в строительном институте в городе Тирана и отражают современную строительную практику Албании. Представлены результаты испытаний трех образцов смесей (нормальный, средней и высокой прочности), приготовленных с использованием пяти различных типов цементов.

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