ARTICLE IN PRESS
Journal of Advanced Research (2015) xxx, xxx–xxx

Cairo University
Journal of Advanced Research

ORIGINAL ARTICLE

Comparison of actions and resistances in different building design codes

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ARTICLE INFO

Article history:
Received 6 August 2015
Received in revised form 31 October 2015
Accepted 10 November 2015
Available online xxxx

Keywords:
Concrete elements
Design codes
Loads
Strength
Steel elements

ABSTRACT

Structural design codes of different countries provide engineers with data and procedures for design of the various structural components. Building design codes from USA, Europe, and Egypt are considered. Comparisons of the provisions for actions (loads), and for the resistance (strength) of sections in flexural and compressive axial loading are carried out. Several parameters are considered including variable actions for occupancy and different material strengths. The comparison is made considering both concrete and steel structures. Issues and consequences of mixing actions from one code and resistance from another code are also discussed.
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Introduction

Structural design codes of different countries provide engineers with data and procedures for design of the various structural components. Differences, sometimes large ones, could be noticed between the codes in the data given for actions (loads), in the provisions for evaluating resistance of sections, in addition to other code requirements for durability, detailing, etc. This paper presents a quantitative comparison of different design building codes from USA, Europe, and Egypt. The considered codes include ASCE 7-10 [1], ACI 318-14 [2], and AISC-360-10 [3] from USA; EN 1991-1:1996 Eurocode 1 (EC1) [4], EN 1992-2:2001 Eurocode 2 (EC2) [5], EN 1993-1-3:2001 Eurocode 3 (EC3) [6], and EN 1994-1-1:2004 Eurocode 4 (EC4) [7] from European Community; and ECP 201-2011 [8], ECP 203-2007 [9], and ECP 205-2007 [10] from Egypt.

The available literature includes many comparative studies for the provisions included in different design codes. Focus is usually given to evaluating the differences in loads, load factors, resistance values stipulated in design codes from United States, Europe, and Japan. Bakhoum and Shafiek [11] compared concrete building design codes from USA, Britain, and Egypt. Comparison focused on the values of actions (loads) and resistance (strength) of sections in flexural.

Nandi and Guha [12] compared the Indian and European design codes considering the material properties, limits on

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Peer review under responsibility of Cairo University.

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http://dx.doi.org/10.1016/j.jare.2015.11.001
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reinforcement area for different elements, and formulas used for calculating ultimate capacity for such elements. El-Shennawy et al. [13] compared the ECP 203-2007 [9] with the equivalent Euro codes through a complete design of a four-storey residential reinforced concrete building. The two designs were evaluated based upon the environmental impact and economical aspects. Hawileh et al. [14] performed a full comparison of the ACI 318 and EC2 design codes considering flexural calculations only. The authors concluded that the EC2 provisions provide a higher safety factor than those for ACI-318. However, the difference is negligible for live/dead load ratios higher than 4. Tabsh [15] focused on comparing the ACI 318 code with the British BS 8110 code regarding the flexural, shear, and axial compressive capacity of members. The study included examining different cross sections while considering different values of live/dead load ratios. The author concluded that the ACI 318 code results in larger cross sections and higher reinforcement ratios. Hassan et al. [16] compared seismic provisions in the Egyptian code for loads (that was under development); Euro Code 8; and Uniform Building Code by focusing on the calculation of lateral forces, member ductility requirements, force reduction factor, and the relevant design accelerations. Bakhoum [17] compared the provisions in American, Japanese, Egyptian, and European codes for highway bridge design. Large differences were highlighted in the traffic action values; however, such differences were considerably reduced when combined with the permanent action values. Bakhoum [18] compared loads used for railway bridge design considering the vertical loads, dynamic factors, longitudinal forces due to traction and braking, and fatigue loads. The comparison included American, Egyptian, and European codes. Bakhoum et al. [19] compared the serviceability limit state requirements in international bridge design codes through analysis of example composite bridges while altering the values of bridge span, bridge width, number of main girders, and the used design code.

This paper focuses on the considered actions (loads) and used design rules for different structural elements including beams and columns while considering steel, concrete, and composite materials. Similarities and differences between the considered design codes are evaluated. The study is meant to provide an insight regarding the applicability of mixing design codes and comparing the safety factors for them. The study also shows the ultimate limit state design for steel elements as a new design philosophy introduced in Egypt in the last few years.

Methodology

Actions and resistances are evaluated and compared for several cases. These include reinforced concrete beams, reinforced concrete columns, steel beams, steel columns, and composite beams. First, the actions and load factors stipulated in different design codes are evaluated. The considered parameters in the study include the following: (i) Permanent actions (D.L.) and variable actions of buildings (L.L.); (ii) Types of building occupancy for variable actions: residential, offices, and shops; and (iii) Action effects: flexural and axial forces. Afterward, the resistances of several structural elements are evaluated for beams and axially loaded short columns. The material properties are fixed throughout the study as follows: Reinforcement yield strength $f_{yk} = 360$ and $500\ \text{N/mm}^2$, structural steel yield strength, $f_y = 240\ \text{N/mm}^2$, and concrete cylinder strength $f_{ck} = 25$ and $40\ \text{N/mm}^2$.

Results and discussion

Actions in the considered codes

Table 1 presents some values of variable actions (L.L.) specified for different types of building occupancy. Comparing the values provided by different codes, differences in values in variable actions can be observed. Large differences in live load intensities are noticed for balconies and corridors in residential buildings; and stair loads in shops. In some cases, the observed differences reached 60% increase in the design live load intensity.

Values of variable actions (L.L.) are combined with permanent actions (D.L.), and then each is multiplied by relevant load factor for ultimate limit state as illustrated in Table 2. The following assumptions are made for evaluating items in

Table 1 Values of variable action intensities for different types of building's occupancy in different studied codes.

Use	Code	Floors (kN/m^2)	Corridors (kN/m^2)	Stairs (kN/m^2)	Balconies (kN/m^2)
Residential	ASCE 7-10 [1]	1.92	4.79	4.79	2.88
	ACI 318-14 [2]	1.90	4.80	4.80	4.80
	EC2 [5]	2.00	2.00	3.00	4.00
	ECP 201-2011 [8]	2.00	2.00*	3.00	3.00
Offices	ASCE 7-10 [1]	2.40	3.83	4.79	3.60
	ACI 318-14 [2]	2.40	4.80	4.80	4.80
	EC2 [5]	3.00	3.00	3.00	3.00
	ECP 201-2011 [8]	2.50	2.50*	4.00	4.00
Shops	ASCE 7-10 [1]	6.00**	6.00**	4.79	–
	ACI 318-14 [2]	6.00**	6.00**	4.80	–
	EC2 [5]	5.00	5.00	5.00	–
	ECP 201-2011 [8]	5.00***	5.00***	5.00***	–

* This value is assumed to be same as that of floors.
** This value is assumed for light manufacturing.
*** The variable action intensity for warehouses and stores is given by $\geqslant 10\ \text{kN/m}^2$ (according to the stored materials).

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