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Evaluation of Traditional Methods in Construction and Their Effects on Reinforced-Concrete Buildings Behavior

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***Abstract*—**Using ETABS software, this study analyzed 23 buildings to evaluate effects of mistakes during construction phase on buildings structural behavior. For modelling, two different loadings were assumed: 1) design loading and 2) loading due to the effects of mistakes in construction phase. Research results determined that considering traditional construction methods for buildings resulted in a significant increase in dead loads and consequently intensified the displacements and base-shears of buildings under seismic loads.

***Keywords*—**Reinforced-concrete buildings, Construction mistakes, Base-shear, displacements, Failure.

I. Introduction

PRESENCE of large amount of experience of recent strong earthquakes around the world and serious demand of quality control implementation in design and construction of buildings, lack of enough attention to this serious issue is still available in developing countries. From earthquake engineering knowledge side, construction of buildings resistible in front of this phenomena is possible but due to some technical problems achieving to quite withstood buildings cannot be ensured [1]-[4]. Main problems of buildings vulnerability can be summarized in lack of proper use of technical knowledge in design and construction of buildings [5], [6]. Majority of small residential buildings in developing countries do not include satisfying structural analysis and practical details of construction and their construction is carried out in lack of precise inspections. In general in buildings construction to avoid futures possible problems following aspects must be taken into consideration; the first one is mentioned as proper and precise design of buildings structures and the second one is explained as correct implementation of details and hypotheses assumed for design in construction phase [7]-[9]. In lack of proper construction and enough attention to the hypotheses assumed in design phase, expectations of structural behavior of buildings elements cannot be realized due to the unpredicted loads available at happening time of earthquakes. It is explained that the dead loads available in buildings structure in lack of proper construction can be different than those the buildings are designed for. Regarding the evaluations carried out on 23 buildings in construction phase it was observed that the real loads after construction phase were more than design loads and consequently, failure of buildings under seismic loads is possible considering these extra loadings.

II. Practical Errors Classifications

In this study, drawbacks, problems, errors in design, and mistakes in construction of reinforced-concrete buildings are evaluated significantly. It is further explained that big mistakes are the not only reason of deduction in structural life of a building but also small errors and mistakes are able to reduce the useful life of a building in future. In Fig. 1 some of common mistakes in construction of traditional buildings are shown. From experiences it is observed that these errors and mistakes can be avoided in design and construction phases with normally little amount of money, but with lack of enough attention to this serious issue, the errors and mistakes will remain in building as a source of future problems and can result in deduction in useful life of these structures. It should be noted that if design phase of a building is terminated, the expenses for errors corrections in construction phase will be more and by passing time in construction phase the costs can even be increased.

Regardless of errors related to the soils contents estimations and foundations of buildings in design phase, main mistakes possible in construction of reinforced-concrete buildings can be mentioned as followings:

1. Formwork
2. Reinforcement-work
3. Concrete-work
4. Lack of enough attention to construction instructions and technical details
5. Quality control issues

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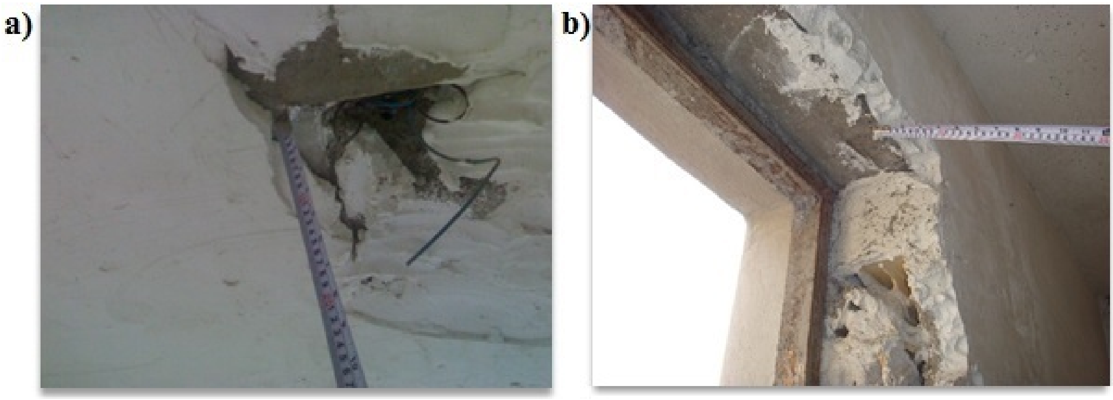

Fig. 1 Common mistakes in construction phase of buildings resulted from lack of enough attention to plaster-work

III. Research Methodology

The main focus of this study was to collect information and its analysis. Gathering information was carried out in the way that was able to cover all statistical cases and on the other hand the value of information must be as level as high and trustable confidence. The experiment stages are explained as following:

A. Research Resources Determination

Experiment resources are divided to two main parts as theoretical and practical ones:

1. Theoretical resources: Literature review, Books, Codes and regulations, etc.
2. Practical resources: Experiments in-situ and observations registered in written format, photos and films.

B. Experiment in-situ

After completion of preliminary phase, experiment in-situ phase starts. In this phase 23 reinforced-concrete buildings in construction phase of province Guilan (Iran) and mainly in 3-5 stories are evaluated. The structures ware collected randomly and mostly in areas with larger number of buildings constructed.

In associate with reinforced-concrete structures in this study, three different operations were observed. These operations are as following:

1- Columns formwork, reinforcement-work and concrete-work
2- Floors formwork, reinforcement-work and concrete-work
3- Measurements of plaster-work dimensions (for walls and ceilings), external view of buildings and floors base-work.

C. Classification and Information Analysis

In this part of study, collected information is classified and then regarding the experiences and theoretical information are analyzed. During analysis it was tried to identify the quality differences between real buildings in construction and Iranian concrete code recommendations. It was further extended in quantity scale and influences of most important mistakes in constructions (increase in floors thicknesses and nonstructural walls resulted from lack of enough attention in construction) were analyzed. Concerning the dimensions of nonstructural elements, the average values of thicknesses for analysis were specified using statistical science.

Thicknesses of mentioned buildings were sampled during plaster-work phase and values measured were tabulated and after the completion of tables, average of thicknesses were studied according to statistical science by considering the weight average method, shown in Table I.

TABLE I
Number of Measured Samples and Average of Observed Thicknesses

Work Type	Number of Samples	Average of thicknesses (cm)
Plasterwork of interior walls	2204	4
Plasterwork of exterior walls	1285	5
Plasterwork of ceiling	575	3
Cementwork of external view walls	490	5
Mortar of floorwork	690	4
Light Weight concrete of floorwork	690	11
Concrete of floor slab	459	6

Dead load of floors, interior perimeter and exterior walls and partitions are calculated regarding the averages of thicknesses observed in former part, shown in Table II and Fig. 2 and the buildings are reanalyzed subsequently.

TABLE II
Assumed Design Loads and Real Loads Observed in Construction

Load location	Assumed load	Real load
Exterior view wall (kg/m)	275	416
Interior perimeter walls (kg/m)	250	325
Partition walls ((kg/m^2)	160	240
Floors (kg/m^2)	550	725

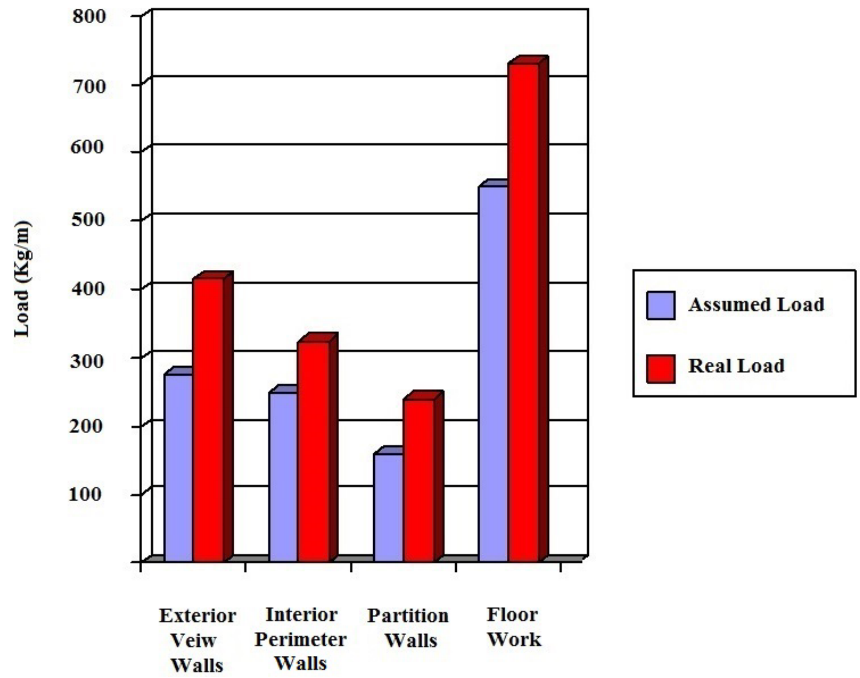

Fig. 2 Comparison between assumed loads in design and real loads in construction

IV. Modeling of Buildings

In this stage buildings are remodeled using information obtained from previous part. ETABS Software was selected for analysis. ETABS software is considered of the ultimate integrated software packages for the structural analysis and design of buildings. The bases of modelling underlie simulations of buildings according to common loading assumptions (assumed design loads) and then according to the results obtained from the experiments carried out (real loads) and finally the results are compared together and their differences are discussed. All building in this study are of reinforced-concrete types with lateral loading system of bending moment frame (moderate deflection).

For further clarification of results, the buildings are divided into 4 parts:

a) Four floors buildings (three story) with area less than 115 m^2 in each floor (buildings 2, 3, 5, 6, 7, 9)
b) Four floors buildings (three story) with area more than 115 m^2 in each floor (buildings 1, 4, 14, 16, 18, 19, 20)
c) Five floors buildings (four story) with area less than 180 m^2 in each floor (buildings 8, 10, 11, 12, 17)
d) Five floors buildings (four story) with area more than 180 m^2 in each floor (buildings 13, 15, 21, 22, 23)

Base-shares and displacements of roof-floors for each group of buildings under assumed and real loads are shown in Figs. 3 & 4.

V. Results and Discussion

Charts evaluation proved that base-shears of buildings in groups (a), (b), (c) and (d) increased 17.8%-21%, 16.7%-18.8%, 16.1%–17.79% and 16–17.5%, respectively. The most increase in base-shears of buildings in group (a) was related to the building number 2 with the least area of 54 m^2 in each floor and most area of walls (1139 m^2). It was also observed that the least increase in base-shears of buildings group (a) was related to building number 7 with the most area of 71 m^2 in each floor and least area of walls (1033 m^2). The most increase in base-shears of buildings in group (b) was related to the building number 18 with the least area of 140 m^2 in each floor and most area of walls (2562 m^2). It was also observed that the least increase in base-shears of buildings group (b) was related to building number 14 with the most area of 223 m^2 in each floor and least area of walls (2221 m^2). The most increase in base-shears of buildings in group (c) was related to the building number 8 with the least area of 92 m^2 in each floor and most area of walls (2482 m^2). It was also observed that the least increase in base-shears of buildings group (c) was related to building number 12 with most area of 144 m^2 in each floor and least area of walls (2388 m^2).

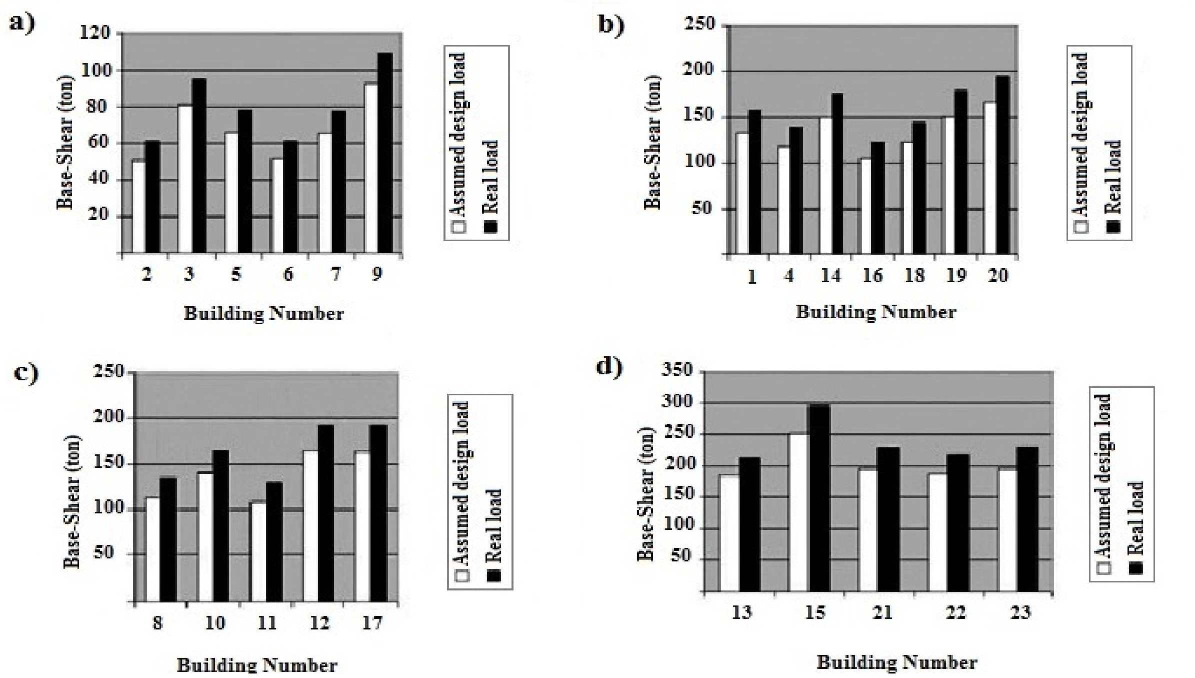

Fig. 3 Comparison between base-shears of buildings with assumed design loads and real loads in construction (Groups a, b, c, d)

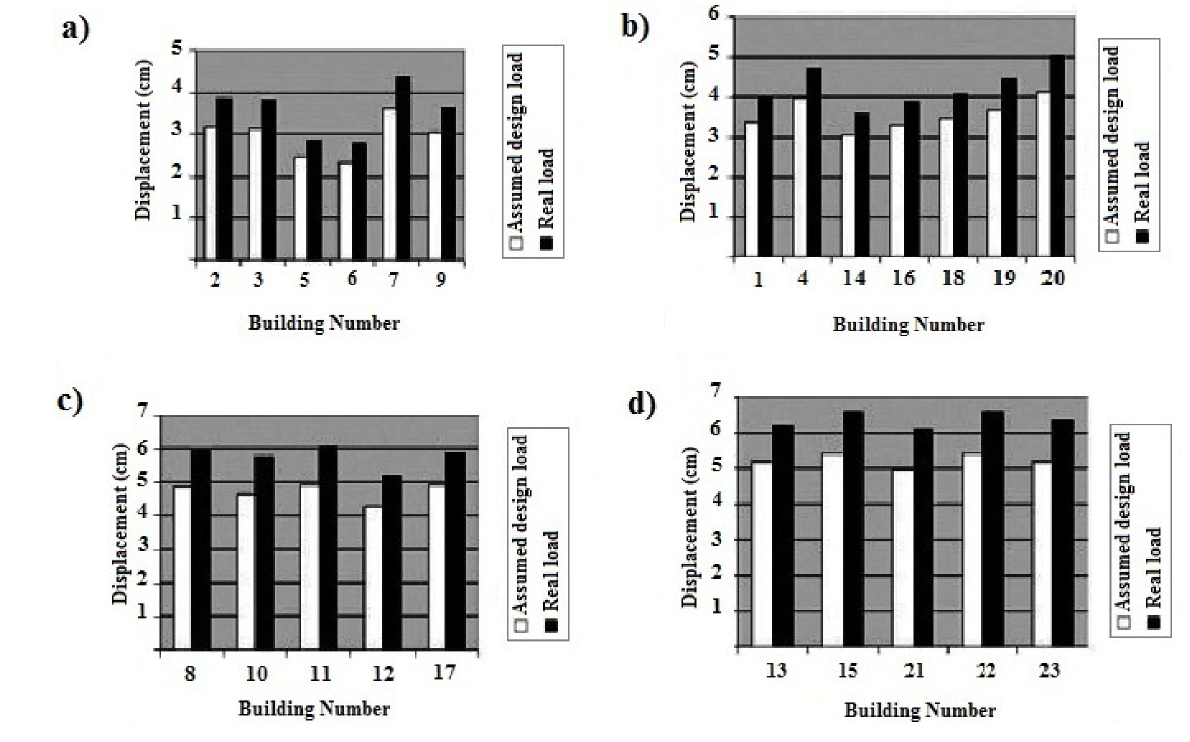

Fig. 4 Comparison between roof-floor displacements of buildings with assumed design loads and real loads in construction (Groups a, b, c, d)

Most increase in base-shears of buildings in group (d) was related to the building number 21 with least area of 171 m^2 in each floor and most area of walls (2452 m^2). It was also observed that the least increase in base-shears of buildings group (d) was related to building number 13 with the most area of 180 m^2 in each floor and the least area of walls (1150 m^2).

Displacements of roof-floors in buildings of groups (a), (b), (c) and (d) were observed to have an increase of 16.2% – 22.4%, 16.7% – 22.5%, 19.7% – 23.9 % and 19.26% – 22.5%, respectively. Research results indicated that with increase in number of floors the displacement of roof-floors increase more in comparison to the base-shears of buildings.

Stress ratio of two critical interior and exterior columns for one building of each group are selected and shown in Figs. 5 & 6. In the column charts the stress ratios of assumed design loads and real loads are shown and the increases in stresses resulted from construction loads are highlighted.

VI. Conclusions

In this study 23 buildings were analyzed for evaluation of mistakes in construction phase and their effects on reinforced-concrete buildings behavior using ETABS software. The buildings were assumed to be under two different loadings during the analysis; the first one was selected as assumed design loading and the second one was selected as loading under mistakes effects in construction phase (real loading). Based on research results, two major conclusion groups were drawn; the first group is introduced as building quality evaluation, and the second one is quantity evaluation.

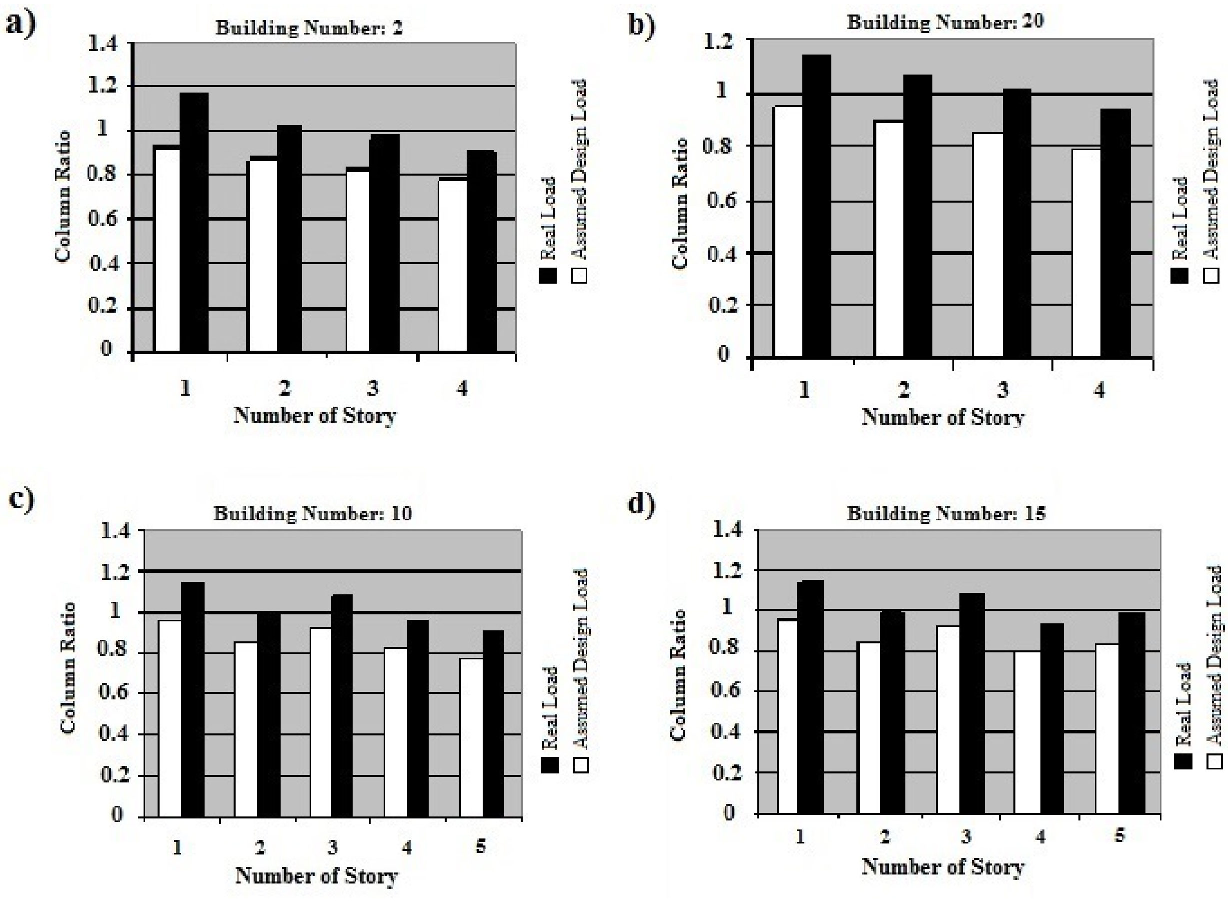

Fig. 5 Stresses ratio for the most critical exterior column of a building in groups a, b, c, d

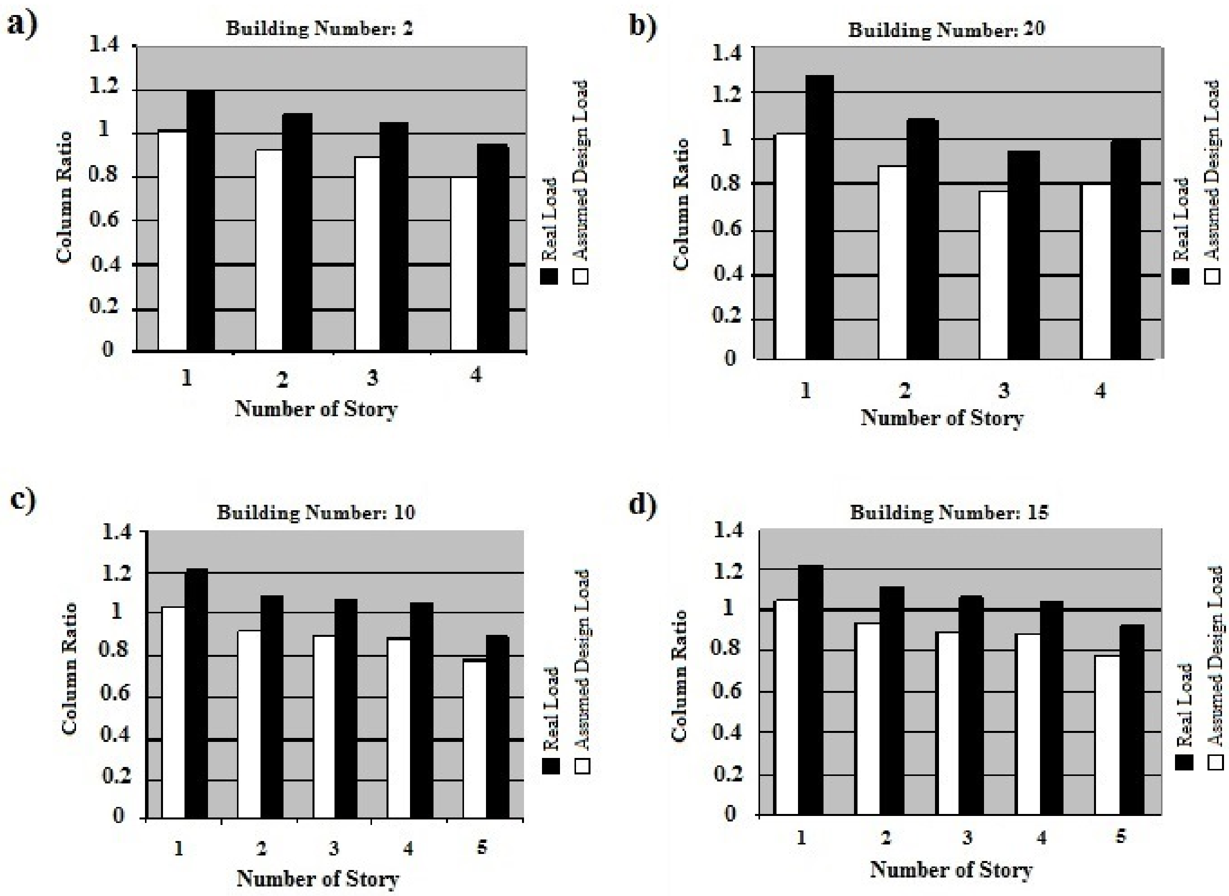

Fig. 6 Stresses ratio for the most critical interior column of a building in groups a, b, c, d

In general, in quality evaluation, extra-critical situation was -not observed for the buildings but majority of buildings was observed not to be under satisfying conditions for the following reasons:

1. Absence of enough information about the importance of construction quality
2. Lack of correct knowledge of effective factors in construction quality
3. Lack of specialists presence in construction phase
4. Shortage of sufficient and proper inspections in construction phase
5. Beneficially-based attitude to buildings industry
6. Absence of explicit implementation of codes instructions in construction
7. Lack of coincidence of codes and regulations with constructions conditions
8. Absence of new practical methods in construction technology
9. Lack of proper management in project site

Quantity evaluation carried out in this study indicates that critical conditions for majority of buildings are unavoidable. Results for quantity evaluation are explained as following (during research the only items in increasing dead loads are mistakes in plaster-works and floor-works):

1. Dead loads resulted from floor-work, partition walls, interior 20 cm thick walls and exterior view walls were observed to be more than values used in design assumptions (by considering mistakes in construction).
2. Research results indicate that real dead load for mentioned elements has increase of 30%-50% than assumed loads in design.
3. With evaluation of 23 buildings it was concluded that base-shears of buildings under real loads (by considering the mistakes in construction phase) had an increase of 16% - 21% in comparison to the base-shears calculated under design assumed loads.
4. For torsional moments and reversal moments an increase of 18% - 31% and 8% - 32% were observed, respectively.
5. Buildings roof-floors displacements showed an increase of 16% - 24% under real loads resulted from mistakes in construction phase.
6. Analytical alternative periods of buildings showed an increase of 6% - 20 % for real loading in comparison to assumed loads in design.

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