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# Comparative Study of Reinforced Concrete Design of Short Columns between BS 8110 and ACI 318-11 (Codes)

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**A B S T R A C T**

In several countries around the world and Libya on of them the absence of a national design code, these leads structural engineers to use BS 8110, ACI 318 and quite a number of other structural design codes for the design of reinforced concrete structures**.** The principles and design approaches of these codes differ from one another. Also, some codes are more economical than others. This study compared BS 8110-97 and ACI 318M-11 in terms of the analysis and design of short column with particular emphasis on the area of longitudinal reinforcements required, with the aim of determining which of the two codes provides the most economic design. The super-structure of a seven-story reinforced concrete service building was modeled, analyzed and design using **Auto Desk R**obot **S**tructural **A**nalysis (2015) program taking into account dead, live and seismic loads. The percentage difference between the areas of steel required by the two codes was calculated with the ACI code as the base line. The average percentage difference for all columns was found to be about 21.5% indicating that the BS 8110 code requires less amount of reinforcement.

## 1 Introduction

### 1.1 Background of Study

Structural Design codes of different countries provide the engineers with data and procedures for design of the structural components. Differences, sometimes large differences, could be noticed between the codes in the data given for actions, in the provisions for evaluating resistance of sections, and also in other code requirements for durability, detailing, there are many existing codes for design are currently using all around the world, for example, Canadian Code (CSA-A23.3-94), Euro code 2 (EC), British Standard BS 8110 and also American Code (most recently ACI 318-19, and older version ACI 318-99). Among the existing codes, Standard ACI 318 is the most common code that has been used for structure design in our country currently. The American Code is produced by governing agency for all concrete construction in the U.S. It was established in 1904 to serve and represent user interests in the field of concrete. The ACI publishes many different standards, but the most commonly referenced standard used by architects and civil engineers is the ACI 318 "Building Code Requirements for Structural Concrete." It is updated every 3 years and the latest version is ACI 318-19 updated in 2019 [1]. Whereby, British Standard is produced by BSI British Standard, a division of BSI Group that is incorporated under a Royal Charter and is formally designated as the National Standard Body (NSB) for the UK. In 1901 under the led of James Mansergh, BSI group had become Engineering Standard Committee, to standardize the number and type of steel Sections, in order to make British manufacturers more efficient and competitive. Over time the standard developed to cover many aspects of tangible engineering, and then engineering methodologies including quality systems, safety and security. Throughout the year BS become more common design tool all around the world.

This research focused on the analysis and design of reinforced concrete columns by using software.



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Columns are vertical members supporting axial compression forces, bending moments and shear forces. The vertical loads from the various floors are cumulated and transmitted by the columns to the foundations. Columns play a major role in structural safety. As a compression member, the failure of a column is more dangerous than that of a beam. The code of practice for column design based on British Standard is included under the BS 8110–97 [11]. while in American Code, it is under ACI318-11.

### 1.2 Objectives

The main objectives of this research drawn as the following:

- To analysis and design of reinforced concrete columns for seven story service building according to BS 8110-97 and ACI 318M-11 by using software (Robot 2015).
- To compare the column design output obtained (with emphasis on the Area of steel required).
- To determine which code provides the most economical design.

## 2 Literature Review

- Yao sheng (2009) "British standard and Eurocode for slender reinforced concrete column design". This investigation evaluates the design steps for slender columns according BS8110 and EC2. Analytical and experimental methods were used to study the behavior of pin-ended slender reinforced concrete columns subjected to uniaxial bending about the minor axis. Buckling failure caused by the instability of a member of structure under perfectly axial compression and without transverse load is being analyzed in this project. The conclusion derived from the analytical investigation on slender reinforced concrete columns that columns with high slenderness ratio tend to have low load capacity, the higher the eccentricity ratio the lower the load capacity. It was also observed that columns cast with higher concrete strength and higher grade of reinforcement are able to sustain higher load capacity.EC2 was found to be more conservative as compared to BS8110 in terms of the study of load capacity ratio with slenderness ratio [29].
- Liew (2009) "British standard (BS 8110) and Eurocode 2 (EC2) for reinforced concrete column design". The study carried out in Malaysia tried to address the perception designers over there have that design using EC2 is very difficult and that it is not very different from BS 8110. The study conducted a review of the design steps for column design using Eurocode 2. Several types of columns were designed according to the two codes and resulting area of steel reinforcements were compared. Results showed that although the design process of EC2 was more technical, they were still easy to understand and follow and design using EC2 was much more economical [18].
- C. Nwofer (2015): Compare BS8110-97 and Eurocode2 for the design of reinforced concrete beam with a particular interest on the area of tension and shear reinforcement required from economical point of view. For the analysis and design, a six-span continuous beam from the roof of a three-story shopping complex with the help of programmed excel spread sheet. The self-weight of the beam was taken as the dead load while the live load was assumed to be unity. They found that Eurocode2 require less amount of tension reinforcement at span as well as support as. The average percentage of both cases is 3.08% and -2.83% respectively. The percentage of shear reinforcement for BS 8110 is more than Eurocode2. For the combination of dead load and impose load are considered, average percentage difference for the span moments of the BS8110 exceed that of the Eurocode2 is more conservative in terms of the partial factor of safety for loading. For a combination of live and dead load considered in this study, the BS8110 required about 1.3% more of the ultimate design loads than that of the Eurocode2. thus, Eurocode2 is more economical design with the required margin of safety Neha Mumtaz (2019): In this paper, a comparative study is presented for analysis and design of reinforced concrete building under seismic forces for four codes Guidelines (IS 1893:2002, Euro code 8, Japan-2007 and ASCE: 7-10) using Staad Pro. The comparative study includes the comparison building base shear, bending moment, shear force, percentage of steel, required area, displacement, and story-drift. For seismic Analysis and design, the building elements like beam and column is also compared using these countries RC building code.
- Iqbal Rasool Dar (2018): The aim of this project is to compare the design codes of IS 456-2007, ACI 318-11code and Eurocode II. The broad design criteria (like stress strain block parameters, L/D ratio, load
- combinations, formula will be compared along with the area of steel for the major structural members like beams, slab, columns, footing to get an over view how the codes fair in comparison with each other. The emphasis will be to put the results in tabular and graphical representation so as to get a better clarity and comparative analysis.
- S. Karthiga.et.al. (2015): present the analysis and design of G+10 for seismic forces using four

international building standards IS1893, Euro Code 8, ASCE7-10 and British Code using STAAD.PRO.V8i. After the design of building a pushover analysis was done in SAP2000 to check the seismic performance of building. After the analysis it was found that maximum shear is obtained from IS code and it undergo minimum displacement than other standards

## 3 Project Description

The framing plan of the seven-story reinforced concrete building was provided and can be seen in figure 3.1. As shown in the framing plan, the building is five spans 5.0m, 4.5m, 6.0m, 4.5m and 5.0m respectively from left to right center-to-center. The spans along the three-span side are 4.0m center-to-center. The height of all the stories of the building is 3.2m. An elevation view of the building is shown in Figure 3.2

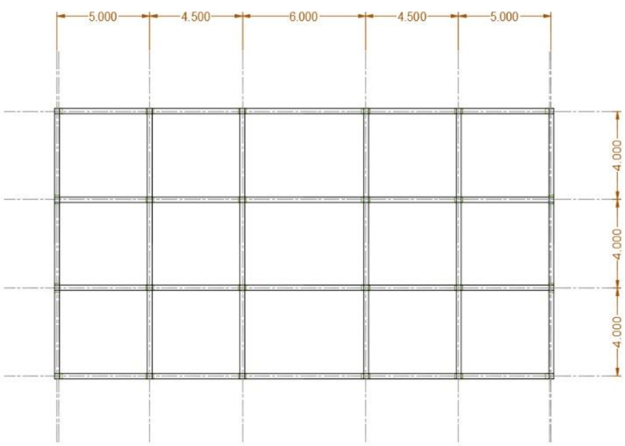


**Figure 3.1**: Floor plan

Owing to the symmetrical geometry of the building as can be seen from the floor plans, some columns have the same loading conditions; these columns were categorized and numbered from C01 to C06 in a convenient way from left to right and from the lower to the upper part of the plan. To differentiate the columns located on specific stories, the columns are identified as 101, 201, 301, 401 and 501 with the first digit indicating the story number while the last two digits indicate column number. Therefore, column with ID 305 is a column numbered 05 in third floor.

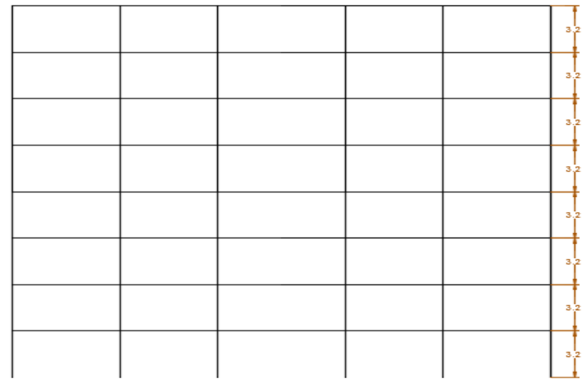

**Figure 3.2:** Front Elevatio

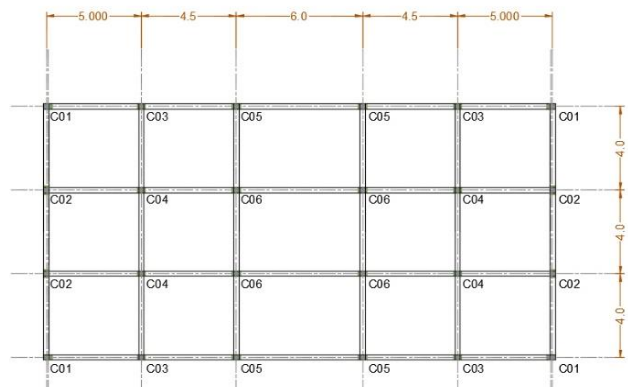


**Figure 3.3:** Column ID

For the structures with different height, different dimensions are taken for structural elements. Table 3.1 shows the dimensions taken for different structural elements in this study.

**Table 3.1:** Dimension of structural elements

| Story | Size of Corner Columns (mm). | Size of Edge columns (mm). | Size of Interior Columns (mm). | Size of beams (mm) | hickness of slabs(mm) |
|---|---|---|---|---|---|
| 1 | 250 * 300 | 250 * 300 | 300 * 500 | 250*700 | 150 |
| 2 | 250 * 300 | 250 * 300 | 300 * 400 | 250*700 | 150 |
| 3 | 250 * 300 | 250 * 300 | 300 * 400 | 250*700 | 150 |
| 4 | 250 * 300 | 250 * 300 | 300 *300 | 250*700 | 150 |
| 5 | 250 * 300 | 250 * 300 | 250 * 300 | 250*700 | 150 |
| 6 | 250 * 300 | 250 * 300 | 250 * 300 | 250*700 | 150 |
| 7 | * 300 | 250 * 300 | 250 * 300 | 250*700 | 150 |

While designing any building, different loads acting on it play a major role. An error in estimation of these loads can lead to the failure of the structure. Therefore, a careful study of loads that are acting on the structure becomes necessary. The loads in particular area must be selected properly and the worst combination of these loads must be evaluated. The dead load in a building should be comprised of the weight of all walls, partitions, floors, roof and should include the weight of all other permanent constructions in that building. Based on the materials used in the building, the dead load (DL) is calculated as 3 KN/m$^2$. Live Load (LL) is taken 4 KN/m$^2$ on the typical floors and 1.5 KN/m$^2$ on the roof, Wall of unit weight 7kN/m. The seismic parameters used in this study are taken according to ASCE 7-10 and are shown in Table 3.2.

**Table 3.2:** Seismic parameters

| Site Class | D |
|---|---|
| **Acceleration Parameter for 1-sec Period, $S_1$** | 0.059g |
| **Acceleration Parameter for short Period, $S_s$** | 0.162g |
| **Risk Category** | III |
| **Importance Factor, I** | 1.25 |
| **Long-Period Transition Period, $T_L$** | 12s |
| **Response Modification Factor, R** | 3.0 |

## 4 Computer Model Using Autodesk Robot Structural Analysis Professional 2015

The computer model for the building as shown in Figure (4.1) consists of panel elements to model the slab and bar elements to model the beams and columns. After defining the structure type, axis, section properties, boundary conditions and loading as shown in figure (4.1), the problem is analyzed and designed by the software for the two Codes.

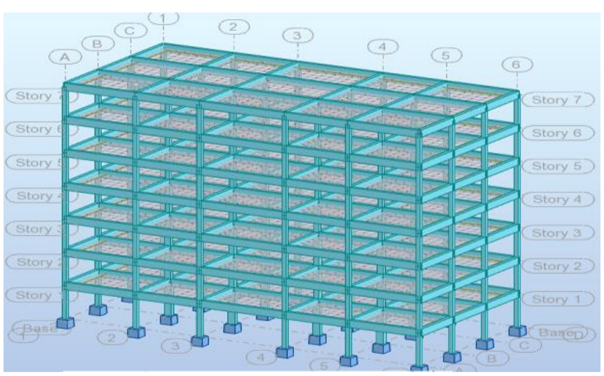


**Figure 4.1:** Model building

## 5 Results and Discussion

Depending to the climatic conditions in Misurata Libya, live, dead and earthquake loads were considered. Analysis was run and axial loads, shear forces and bending moments acting on the columns for different loads combinations as stipulated by the codes were obtained as shown in the following Figures.

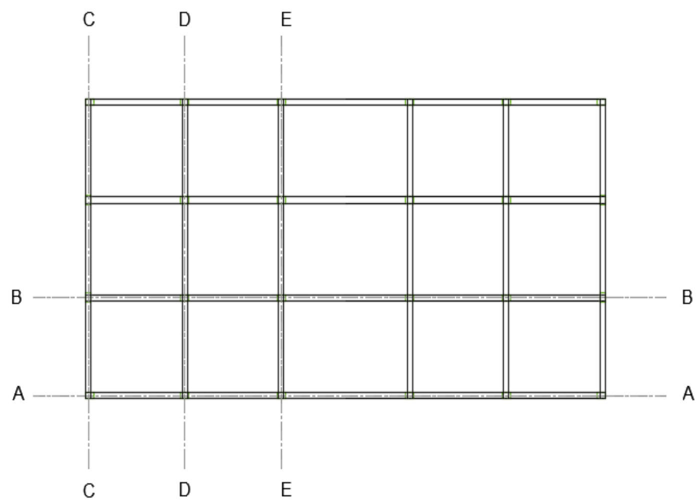


**Figure5.1:** Plan shows section taken

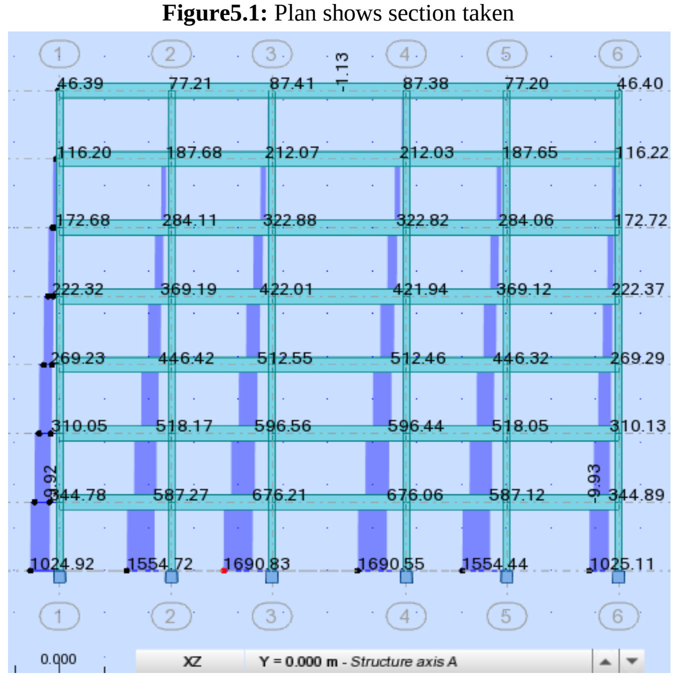


**Figure 5.2:** Axial Forces on Columns – Section A-A

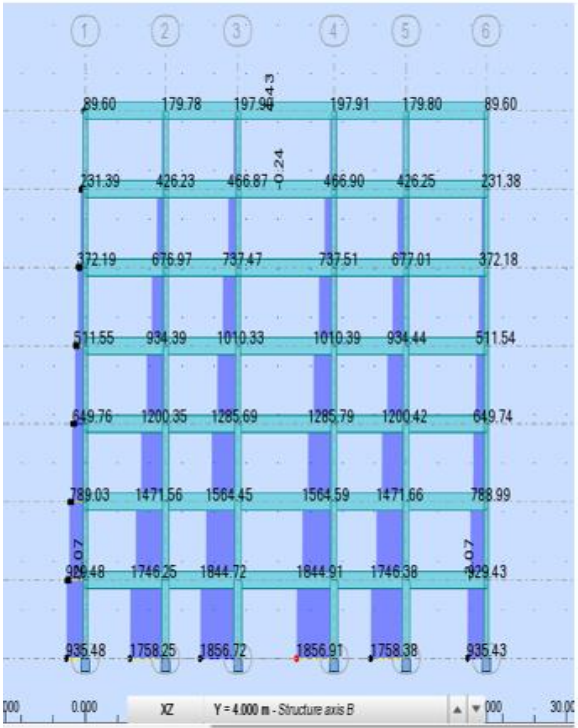


**Figure 5.3:** Axial Forces on Columns – Section B-B

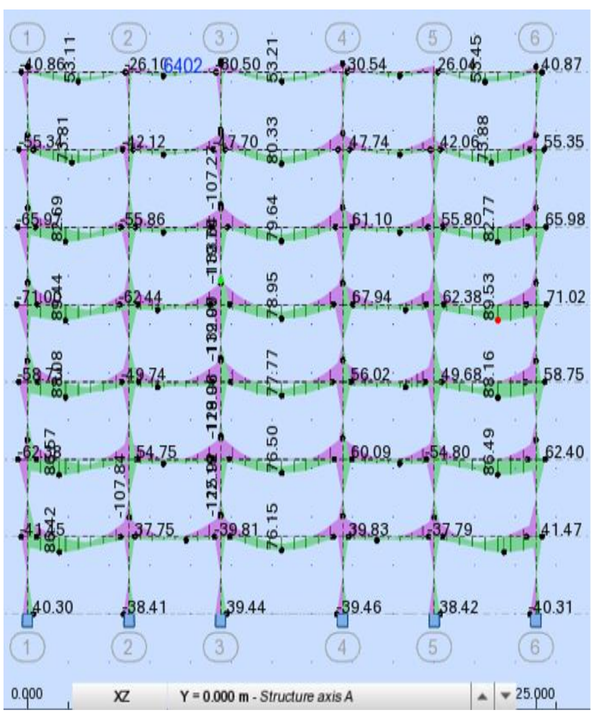


**Figure 5.4:** Bending moment for section A-A

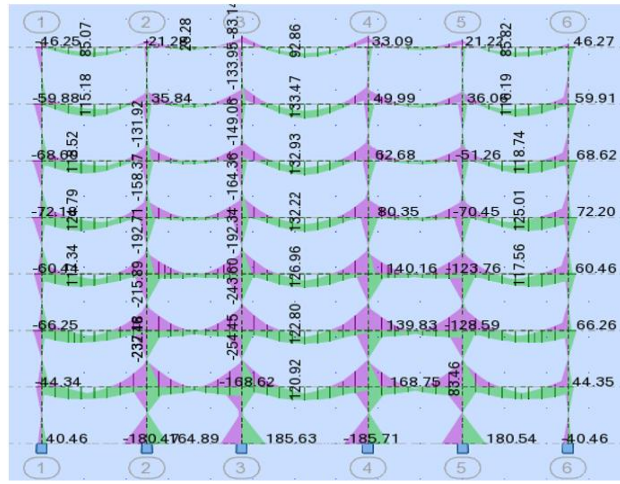


**Figure 5.5:** Bending moment for section B-B

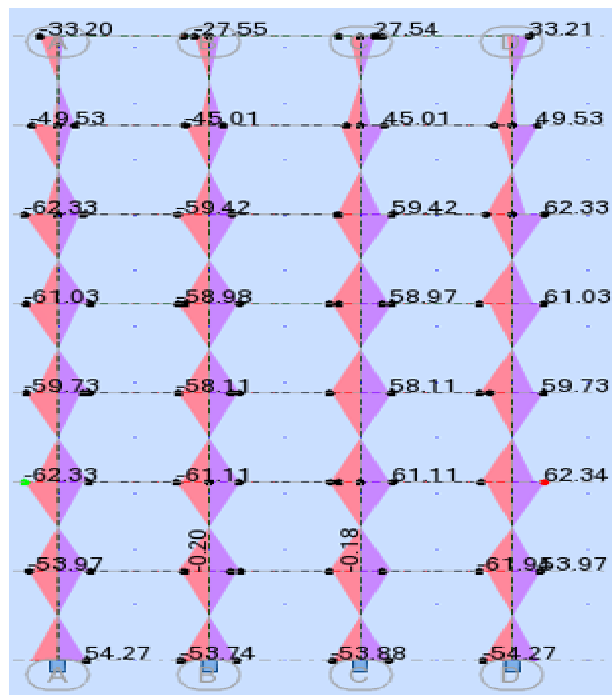


**Figure 5.6:** Bending moment for section C-C

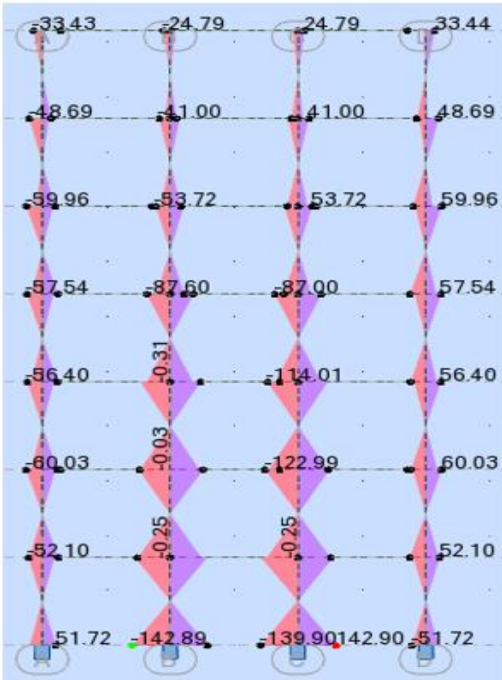


**Figure 5.7**: Bending moment for section D-D

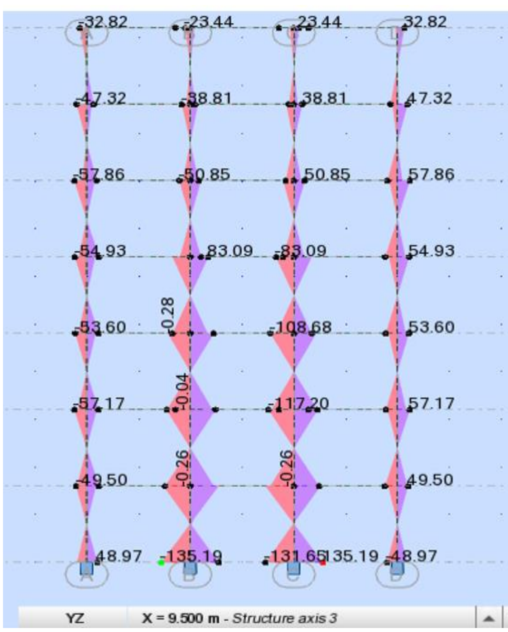


**Figure 5.8:** Bending moment for section E-E

The results of the design of the columns of the most critical load cases as determined automatically by the RSA program, for comparative analysis, the percentage difference between the areas of steel required was calculated for worst design case. The ACI 318M-11 values are kept as a baseline, therefore a positive value of percentage difference indicates that the amount of steel required by ACI 318M-11 is less than that required by BS 8110-97 and vice-versa. To further illustrate these results, graphs of area of steel required by each design codes for selected corner, edge and interior columns were plotted as shown in the next figures and tables.

**Table 5.1:** Area of Steel Required for Corner Column

| Column ID | Required Area of Steel ($mm^2$) | | Percentage Difference (%) |
|---|---|---|---|
| | ACI | BS | |
| 101 | 2460 | 2289 | 6.95 |
| 201 | 3456 | 2548 | 26.27 |
| 301 | 3216 | 2074 | 35.51 |
| 401 | 3624 | 2081 | 42.58 |
| 501 | 3431 | 2164 | 36.93 |
| 601 | 1733 | 1599 | 7.73 |
| 701 | 990 | 1065 | -7.58 |
| Average | | | 26.92 |

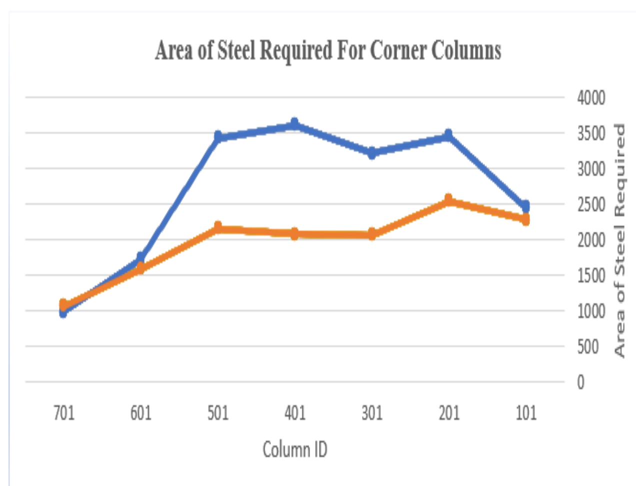


**Figure 5.9:** Area of Steel Required for Corner Column

**Table 5.2**: Area of Steel Required for Edge Column

| Column ID | Required Area of Steel (mm²) | | Percentage Difference (%) |
|---|---|---|---|
| | ACI | BS | |
| 102 | 3945 | 3308 | 16.15 |
| 103 | 4200 | 3203 | 23.74 |
| 105 | 4515 | 3375 | 25.25 |
| 202 | 4230 | 3323 | 21.44 |
| 203 | 3990 | 3068 | 23.11 |
| 205 | 4058 | 3113 | 23.29 |
| 302 | 3548 | 2640 | 25.59 |
| 303 | 3555 | 2213 | 37.75 |
| 305 | 2933 | 2258 | 23.01 |
| 402 | 3758 | 2498 | 33.53 |
| 403 | 2543 | 1928 | 24.18 |
| 405 | 2550 | 1860 | 27.06 |
| 502 | 4043 | 2303 | 43.04 |
| 503 | 2535 | 1718 | 32.23 |
| 505 | 2648 | 1620 | 38.82 |
| 602 | 2340 | 1463 | 37.48 |
| 603 | 750 | 1095 | -46 |
| 605 | 1223 | 960 | 21.5 |
| 702 | 833 | 893 | -7.2 |
| 703 | 750 | 720 | 4 |
| 705 | 750 | 645 | 14 |
| Average | | | 25.95 |

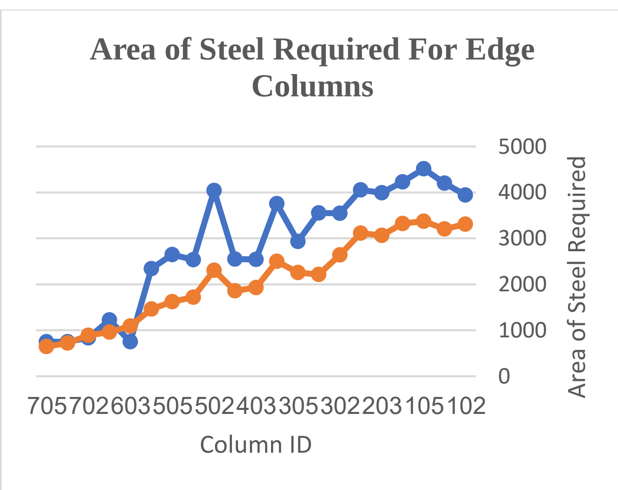


**Figure 5.10:** Area of Steel Required for Edge Column

**Table 5.3**: Area of Steel Required for Interior Column

| Column ID | Required Area of Steel (mm²) | | Percentage Difference (%) |
|---|---|---|---|
| | ACI | BS | |
| 104 | 6960 | 5670 | 18.53 |
| 106 | 7125 | 5700 | 20 |
| 204 | 6348 | 5472 | 13.8 |
| 206 | 6912 | 5448 | 21.18 |
| 304 | 4680 | 4260 | 8.97 |
| 306 | 5304 | 4200 | 20.81 |
| 404 | 3870 | 3555 | 8.14 |
| 406 | 4302 | 3546 | 17.57 |
| 504 | 2468 | 2490 | -0.89 |
| 506 | 2835 | 2513 | 11.36 |
| 604 | 750 | 968 | -29.07 |
| 606 | 750 | 953 | -27.07 |
| 704 | 750 | 330 | 56 |
| 706 | 750 | 308 | 58.93 |
| Average | | | 15.6 |

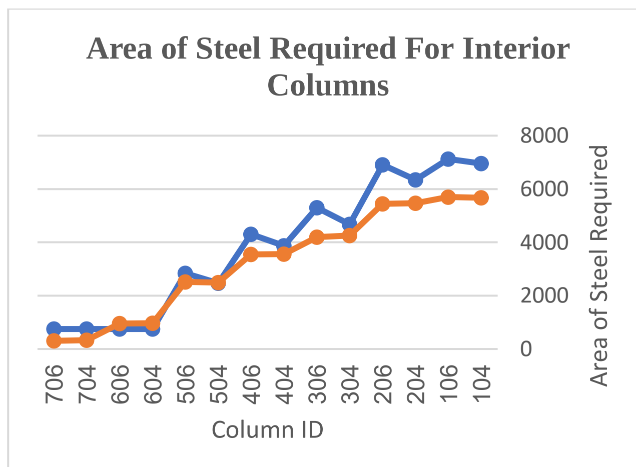


**Figure 5.11:** Area of Steel Required for Edge Column

**Table 5.4:** Area of Steel Required for Each Story

| Story | Required Area of Steel (mm²) | | Percentage Difference (%) |
|---|---|---|---|
| | ACI | BS | |
| 1 | 116820 | 94180 | 19.38 |
| 2 | 115976 | 91888 | 20.77 |
| 3 | 92944 | 70580 | 24.06 |
| 4 | 92460 | 71832 | 22.31 |
| 5 | 71840 | 51232 | 28.69 |
| 6 | 30184 | 28152 | 6.73 |
| 7 | 19292 | 15844 | 17.87 |
| Average | | | 19.97 |
| Total | 539516 | 423708 | 21.47 |

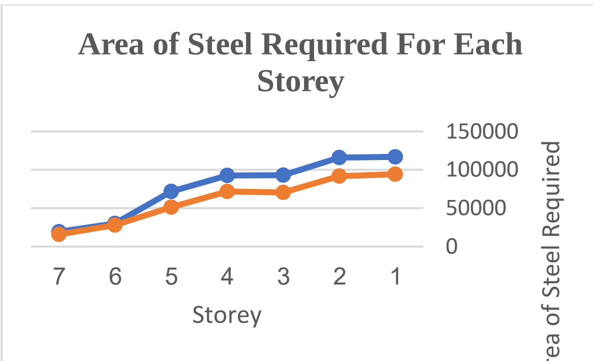


**Figure 5.12:** Area of Steel Required for Each Story

The percentage difference between the areas of steel required by the two codes was calculated with the ACI code as the base line. For the combination of loads considered in this study; the average percentage difference for corner, edge and interior columns are about 26.92%, 25.95% and 15.6% respectively. The overall average for all columns was found be about 21.5 %. The results show that ACI code requires more area of steel for all columns.
This difference in trend is attributed to the different manner adopted by both codes to determine the design loads. In BS 8110 design moment are determined as the moment in either the major or minor axis increased by a certain percentage (β) of the moment from the other direction as opposed to the approximate methods used by the ACI 318. Therefore, the design moments considered by ACI 318 are much larger.

## 6 Conclusions and recommendation

In the absence of a national design code, the structural engineers in Libya use the BS 8110, Euro code 2, ACI 318 and quite a number of other structural design codes for the design of reinforced concrete structures. However, these engineers frequently compare the stipulations in these codes seeking points of similarities and differences. Economy is also a major point of concern. This study compared BS 8110-97 and ACI 318M-11 in terms of the analysis and design of short column with particular emphasis on the area of longitudinal reinforcements required, with the aim of determining which of the two codes provides the most economic design. The super-structure of a seven-story reinforced concrete service building was modeled and analyzed using Robot Structural Analysis program taking into account dead, live and seismic loads; the result of the analysis was used to design the columns time with the aid of Robot Structural Analysis program. The percentage difference between the areas of steel required by the two codes was calculated with the ACI code as the base line. The average percentage difference for all columns was found to be about 21.5% indicating that the BS 8110 code requires less amount of reinforcement.
The results of this comparative study led to the following conclusions:
The basic design principles of the two codes are the same; they are both based on the limit-states design principle. Their design approaches are very similar; both are aimed at designing safe and economic structures. The only differ in details.
The ACI code is more conservative in terms of the partial factors of safety for loads, for a combination of live and dead load considered in this study.
Considering the fact that the overall average for all columns was found to be about 21.5%, design of the columns using the BS code is more economical as it requires less reinforcement than the ACI code.

### Recommendation

The BS code is recommended over the ACI code for the design of short columns in Libya as it provides a more economical design with the required safety.
As some of the provisions of these codes do not tally with the conditions in Libya, there is a need for Libya to develop its own national codes which will be suitable to its conditions.

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