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EC2 And ACI 318M-14 Flexural Provisions For Beams Compared Via A Simplified Study

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***Abstract*—The flexural design of a 6 metre simply supported reinforced concrete beam having fixed dead to imposed load ratio but varying effective depth/breadth (d/b) ratios and concrete compressive cylinder strengths was executed using two design codes EC2 and ACI 318M-14. The aim of the study was to enable a direct comparison between the flexural provisions of the afore-mentioned codes in respect of reinforced concrete beam designs. It was found that for a low concrete compressive strength of 20 MPa and shallow beams (0.8 < b/d < 1.25) EC2 required 20.5 % more tensile reinforcement compared to ACI 318M-14. However for more normal beams (0.4 < b/d < 0.67) EC2 needed 15.6 % more tension steel. With a higher compressive strength of 50 MPa, EC2 required 20 % and 14.4 % more tensile reinforcement compared to ACI 318M-14 for shallow and normal beams respectively. In respect of compression steel however and low concrete compressive strengths, EC2 needed 19.4 % less and 63.3 % more reinforcement for shallow and more normal beams respectively in relation to ACI 318M-14. With reference to higher concrete compressive strengths and shallow beams, EC2 required 13.4 % less compression steel. It was concluded that additional studies should be carried out for various dead to imposed load ratios in order to provide a more complete comparison of the flexural provisions of both codes.**

***Keywords*— Code, reinforced concrete, beam, flexural design, reinforcement**

I. INTRODUCTION

Since the early part of the 20th Century, considerable attention has been given to the development of building codes for reinforced concrete. The importance of structural design codes is primarily to provide guidelines and procedures for the design of various structural elements and building structures, all with the aim of ensuring public health and environmental safety. While all aspects of these design codes and recommendations might not have a statutorily or legally binding basis however, they do provide a compendia of good scientific and engineering principles which if adhered to would in general result in the production of safe and durable structures. Furthermore such structural standards are reviewed periodically in the light of new research findings or suggested improvements. However these reviews and their implementation may span from 3 to 5years or more, dependent on a host of factors, including geographical. The present study is concerned with the ACI 318M-14 and the EC2 codes [1–2] for the design of concrete structures.

The ACI 318M-14 code [1] and its predecessors have been widely used for several decades. According to Park and Paulay [3], the ACI 318 building codes have been broadly accepted in several countries; in addition they have strongly influenced the codes of many other nations. Evidence for the latter can be found in the impact made by the series of special publications on particular aspects of reinforced concrete behaviour and design such as, ACI PRC-445.1-12 [4] dealing with torsion in structural concrete, SP-042 [5] covering shear in reinforced concrete and SP-043 [6] focusing on deflections in concrete structures. Apart from all these, reference should also be made to the profound influence regular publications such as the ACI Materials Journal and the ACI Structural Journal continue to make towards the development of reinforced concrete research, design and construction practices worldwide.

Eurocode 2 or EC2: Design of concrete structures [2] together with its sister documents EC0: Basis of structural design and EC1: Actions on structures, were introduced as part of an alternative set of standards to replace British and other European national codes. Collectively these standards provide common design criteria and methods to fulfil specified requirements for strength, stability, fire resistance, durability and economy. Equally importantly, these Eurocodes have also aided the communication of construction services between member states in the European Union and provided a unifying foundation for research and development in the construction sector. They have strengthened the competitiveness of the European construction industry, and in removing obstacles from previously national codified practices, they have also reinforced the effectiveness of the continental common market [7]. EC2 has become entrenched since April 2010 as the standard design code for reinforced concrete in the United Kingdom. The earlier British code BS 8110-1997 [8] as well as other European member states individual national codes have been withdrawn.

Following from the above, it is apparent that there are two major reinforced concrete structural design codes being utilized namely ACI 318M-14 code or its revisions and the EC2 standard. The impact of these two design codes have been felt in several parts of the world largely through dissemination of design guides, publications, and research findings. However there are still large parts of Africa and the Middle East or even Asia where there are no national structural design codes or the development of such is still in its infancy, and real knowledge and awareness of the features and differences between ACI 318M-14 and EC2 are somewhat lacking. If these issues are coupled with the peculiar economic and environmental consideration of such regions, it becomes clear that there is a need for a comparison such as that undertaken in the present study. Prior to such an exercise however, it is useful to briefly survey some of the previous investigations carried out in this respect.

Jawad [9] compared the strength design requirements of ACI 318M-02, BS 8110 and EC2 and concluded that EC2 was more liberal in partial safety factors and strength design than ACI 318M-02. More particularly with regards to flexural considerations, for lower reinforcement ratios ($\rho < 0.02$) the ACI design formula gave marginally higher moment capacities than EC2. However at higher reinforcement ratios ($\rho > 0.03$) for doubly reinforced sections, the EC2 formula yielded noticeably much higher moment capacities due to the influence of the compression steel.

Ameli and Ronagh [10] studied the treatment of torsion in reinforced concrete beams based on the standards AS 3600 (2001), BS 8110 (1985), ACI 318-02, EC2 and CSA A23.3-94 and concluded that none of the standards accurately predicted the ultimate torque for a series of eleven tested beams. Bentz and Collins [11] compared the shear provisions of EC2, ACI and CSA to a database of 1601 experimentally observed shear failures. They concluded that the ACI code yielded unconservative predictions while EC2 provided poor correlations, partly due to not accounting sufficiently for size effects as well as the overestimation of the influence of high reinforcement percentages.

Hawileh et al. [12] compared the flexural design provisions of ACI 318-05 and EC2 in respect of safety concepts, design assumptions, moment capacities, ductility, minimum and maximum reinforcement ratios and load safety factors. They found that the EC2 flexural provisions were slightly more conservative than those of ACI 318-05. Also EC2 resulted in higher safety factors for low live load/dead load ratios. However as the latter approached a value of 4.0, the differences between both codes decreased considerably.

The analysis and design of a reinforced concrete four storey building was conducted by Franklin and Mensah [13] in their comparative study of the EC2 (2004) and BS 8110-1997 codes. With respect to the critical continuous beam section examined, the EC2 moments at internal supports generally exceeded the BS 8110 values by 0 – 8.5 % at all levels of moment distribution. However regarding maximum span moments in the continuous beam, EC2 moments were lower than the BS 8110 counterparts by 4.5 % – 9 % for moment distributions up to 20 %. For 30 % redistribution, the shortfall or deficit was about 14.3 % although this was adjudged to be an isolated case.

An extensive comparative study of the design provisions for bending, shear and torsion of ACI 318-08 and BS 8110-1997 was conducted by Alnuaimi et al. [14]. They concluded that for the same value of unfactored loads, BS 8110 required less reinforcement than ACI 318. However with the inclusion of the load safety factors to determine the design loads, BS 8110 needed more reinforcement than ACI 318. Notwithstanding, the minimum area of flexural reinforcement required by BS 8110 was lower than ACI 318.

Nwofor et al.[15] carried out a comparative study on the flexural and shear requirements for the design of a six-span continuous beam using BS 8110-1997 and EC2 (2004). They found that BS 8110 needed more areas of tension reinforcements at spans (≅ 3.1 %) and at supports (≅ 2.8 %) than EC2. In respect of shear reinforcement, the BS 8110 requirements exceeded that of EC2 by about 62%. They concluded that on the whole, EC2 provided a more economical design. Mohanty and Datta [16] stressed the need for the development of common codal provisions in their comparative study of flexural requirements for the Indian standard IS 456 (2000), BS 8110-1997, ACI 318-08 and EC2. A parametric study was conducted for three groups of simply supported reinforced concrete beams. It was concluded that EC2 provided the least area of flexural reinforcement for constant dead load and varying live loads. However for constant live load and varying dead loads, ACI 318 provided the least area of flexural reinforcement. These results were attributed to the difference in load safety factors of the various codes.

A comparison of actions and resistances of building design codes from the USA, Europe and Egypt was executed by Bakhoum et al. [17]. Their study encompassed reinforced concrete beams and columns, steel beams and columns, and composite beams. Different types of building occupancy were considered. In regards to reinforced concrete beams, they opined that the ultimate moment of resistance was 5 % – 14 % higher for ACI 318-14 than for EC2 (2004) and ECP 203-2007. This difference increased marginally with increase in reinforcement ratio ρ. Also ACI 318-14 generally required smaller sections than EC2 and was less conservative or more economic by 2 % – 10 % depending on ρ and the yield strength of the reinforcement.

Nwoji and Ugwu [18] did a comparison of the analysis and design provisions for BS 8110-1997 and EC2 (2004) in respect of a two-storey building comprised of two suspended floors and one reinforced concrete roof slab. It was discovered that for the critical continuous beam section investigated, EC2 moments at internal supports exceeded the BS 8110 values by 0 –8.5 % at all levels of moment distribution. In relation to maximum span moments in the continuous beam, the EC2 moments were lower than the BS 8110 values by about 4.5 % – 9 % for moment redistributions up to 20 %. At 30 % redistribution, the difference was about 14.3 % although this was considered to be an isolated case.

The effect of combined actions of torsional moments, bending moments and shear forces on 15 reinforced concrete beams was investigated by Amulu and Ezeagu [19] using BS 8110-1997, ACI 318-11 and EC2. All beams had a characteristic cube strength of 30 MPa and reinforcement strength of 460 MPa. It was concluded that EC2 predicted the highest ultimate bending moment strengths while BS 8110 gave the least values. Nevertheless the predictions for all codes were quite conservative. Further research was recommended based on the dimensions of beam cross-sections and eccentricity of loading in order to ascertain the effects on the capacity of beams to resist combined loads.

Izhar and Dagar [20] compared the reinforced concrete design procedures of IS 456 (2000), ACI 318M-05, BS 8110-1997, CSA A23.3-2004 and EC2 (2004) using a G+10 office building analyzed and designed by means of computer software, but keeping the cross-sections of the structural elements same for each code. However to aid comparisons, the dead, live and wind loads were based on IS 456 (2000). They concluded that the IS 456 gave the least flexural reinforcement while the CSA code produced the maximum. However for slabs, longitudinal and transverse reinforcement were least for EC2 and maximum for ACI 318.

A review of the design of reinforced concrete members based on design codes relevant to the USA, Europe, India and the United Kingdom was carried out by Bano et al. [21]. Comparative studies dwelt on aspects such as load factors and load combinations as well as design provisions for structural elements like beams, columns and slabs. However no further comments will be made herein of their work, since their study was basically a commentary of previous findings in the literature.

From the foregoing discussions and reviews, it is obvious that although much work has been done by way of comparative study of codal provisions, several of the investigations are too broad in scope, for example Bakhoum et al. [17], or a single case study has been examined leading to results from such a study that could be considered isolated cases. In general only a few parametric studies have been carried out. In view of these drawbacks the present authors have conducted a parametric study based on a simplified model. In order to arrive at meaningful and credible findings, a comparative study of ACI 318M-14 and EC2 (2004) design provisions was carried out involving flexural considerations only.

II. METHODOLOGY

Both Eurocode 2 and ACI 318M-14 adopt the limit state design philosophy. Bearing in mind the guidelines enunciated previously on the need to adopt a simplified model, the authors selected a simply supported reinforced concrete beam of span L = 6m, centre to centre of supports. The beam formed a part of a structural system comprising 230 mm thick reinforced concrete walls. Consequently a beam breadth b = 230 mm matching the wall thickness was chosen. Careful consideration was given to the choice of loadings, and the authors elected to use characteristic dead and imposed loads g_k and q_k of 28 kN/m and 9 kN/m respectively.

In practical situations it is generally more economical to design deep and narrow beams as opposed to wide and shallow ones. However the latter may on occasions be more advantageous due to benefits and savings in floor-to-floor heights and hence overall building economy. This notwithstanding, use of wide and shallow beams would entail additional reinforcement. With these considerations in mind and the need to encompass the complete range of breadth/overall depth or b/h values for the intended parametric study, h values of 250 mm with progressive increments of 50 mm up until 700 mm were adopted in turn. The corresponding effective depths d were 190 mm with progressive increments of 50 mm up until 640 mm. The effective depth to the compression reinforcement d′ was fixed at 50 mm in all cases. These values meant that d/b ratios for the study ranged from 190/230 or 0.826 for the shallowest beams to 640/230 or 2.783 for the deepest beams. It is generally accepted that for beam sections spanning up to 8 m, a d/b ratio between 1.5 and 2.5 should prove economical. Hence the range adopted by the authors of 0.826–2.783 for the 6 m span beam adequately covers the spectrum or band of economical designs.

It should be borne in mind that in the choice of depth of beam sections utilized, deflection considerations have not been of primary focus herein. Considering the ACI 318M-14 code, a minimum overall depth h of $(L/16)(0.4 + f_y/700)$ or about 420 mm for the 6 m simply supported beam is required. With regards to Eurocode 2, basic span/effective depth ratios L/d are dependent on the required percentage tension reinforcement ratio ρ as well as the characteristic cylinder compressive strengths, f_{ck}. From BS EN 1992 (2004) assuming an average reinforcement ratio ρ of 1.0 %, the basic L/d ratio would be in the approximate range 14 – 18.6 for f_{ck} values in the range 20–50 MPa. This would imply that overall depth values h would be in the range 375 – 495 mm, taking d/h to be approximately 0.87, or an average value of 430 mm which is not too dissimilar in comparison to the ACI 318M-14 value. Hence the selected range of h adopted for the parametric study, 250 mm – 700 mm could be considered sufficiently broad.

In relation to the choice of concrete strength, it was decided to embrace the range covered by general purpose applications of normal weight concrete. While a minimum compressive cylinder strength f_{ck} or $f_c{}'$ of 20 MPa is considered acceptable, there is generally no limit in practical designs for the maximum compressive strength. For the present purpose it was decided to peg or limit this value to 50 MPa. Consequently in the parametric study f_{ck} or $f_c{}'$ values of 20 MPa with progressive increases of 5 MPa up until 50 MPa were utilized. This selection was deemed to adequately cover the majority of applications encountered in practice apart from for example, special moment frames and special structural walls.

The characteristic yield strength permitted in EC2 ranges from 400 to 600 MPa. The United Kingdom reinforcement industry adopts a characteristic yield strength f_{yk} of 500 MPa and this value was utilized in the current study. For flexure, ACI 318M-14 permits a maximum yield strength for non-prestressed reinforcement f_y of 550 MPa, hence the 500 MPa selected previously satisfies the requirements of both codes.

In respect of the comparative study, the procedure adopted was to employ the design equations of both EC2 and ACI 318M-14 to determine the required areas of flexural tensile and compressive reinforcements. For this purpose the simplified rectangular stress block given in each code was utilized. The parametric study was carried out for the previously stated characteristic dead and imposed loads of 28 kN/m and 9 kN/m respectively in conjunction with various combinations of beam breadth to effective depth ratios, as well as cylinder compressive strengths. A summary of some of the major items for the study series and data is shown in Table 1. Microsoft Excel 2010 was adopted to carry out the computations and analysis of input data.

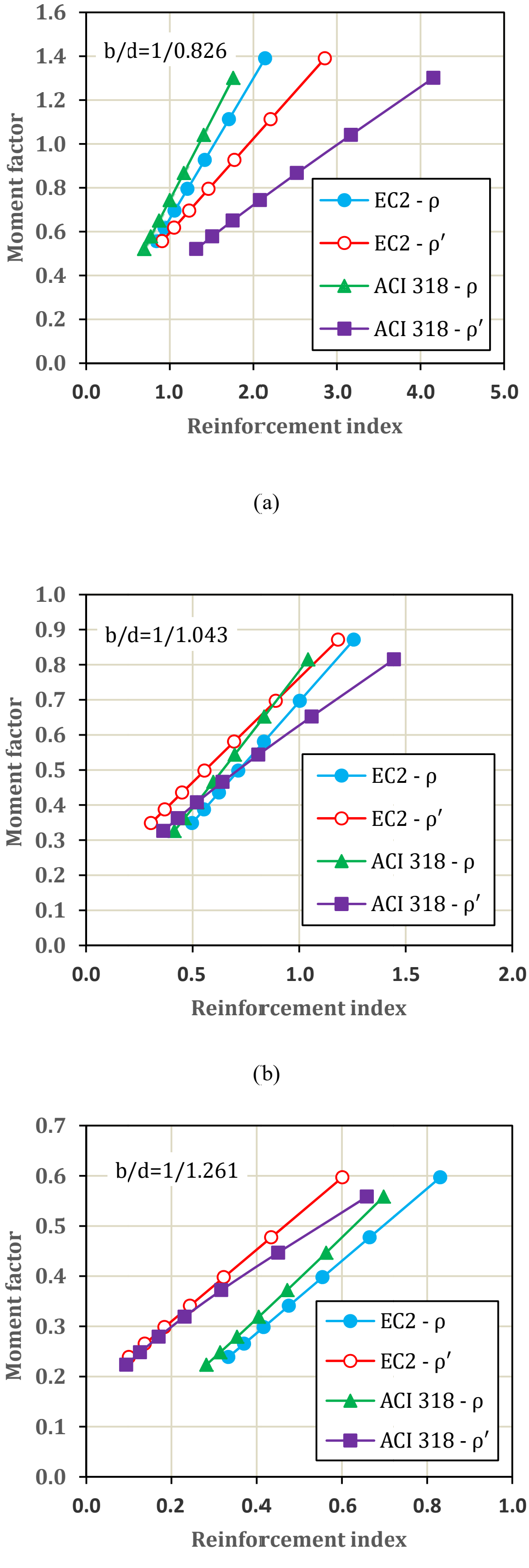
TABLE 1: MAJOR PARAMETERS USED IN THE STUDY

Series*	b (mm)	h (mm)	d (mm)	d′ (mm)	f_{ck} , f_c' (MPa)
1	230	250	190	50	20-50
2	230	300	240	50	20-50
3	230	350	290	50	20-50
4	230	400	340	50	20-50
5	230	450	390	50	20-50
6	230	500	440	50	20-50
7	230	550	490	50	20-50
8	230	600	540	50	20-50
9	230	650	590	50	20-50
10	230	700	640	50	20-50

*For each series, $f_{ck} = f_c' = 20, 25, 30, 35, 40, 45, 50$ MPa in that order.

III. RESULTS AND DISCUSSION

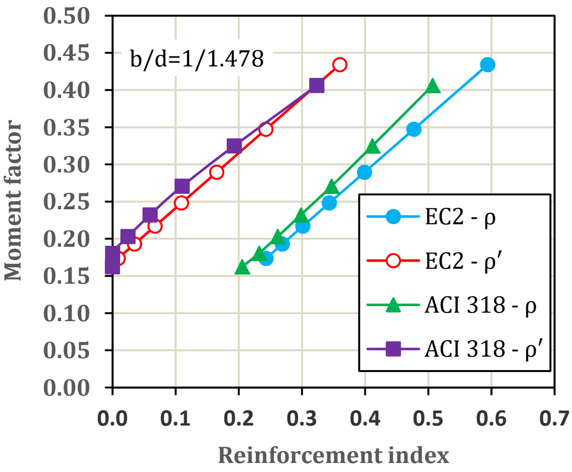
In Fig. 1(a)–(j) the variation of the moment factor with the reinforcement index has been plotted for both EC2 and ACI 318M-14. In this regard the moment factor K was taken as the ratio of the factored design moments $\mathrm{M/(f_{ck}bd^2)}$ and $\mathrm{M/(f_c'bd^2)}$ for EC2 and ACI 318 respectively. The reinforcement indices $\rho\, f_{yk}/f_{ck}$ or $\rho'\, f_{yk}/f_{ck}$ and $\rho\, f_y/f_c'$ or $\rho'\, f_y/f_c'$ are with reference to the EC2 and ACI 318 codes in that order. In this context, ρ and ρ′ are the reinforcement ratios with respect to the tension and compression steel respectively.



(a)

(b)

(c)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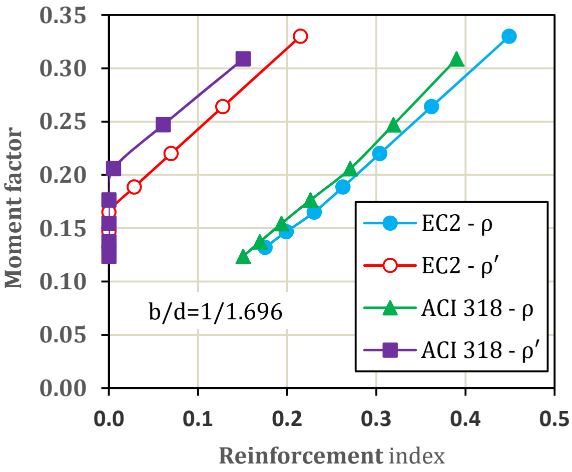
EC2 - ρ′
ACI 318 - ρ
ACI 318 - ρ′

(d)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Reinforcement index
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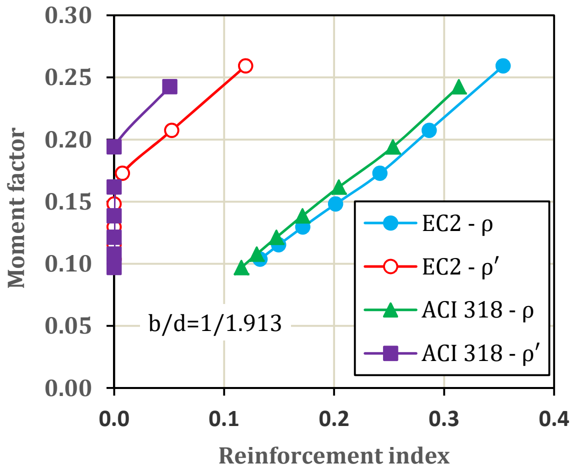
0.4
0.5
EC2 - ρ
EC2 - ρ′
ACI 318 - ρ
ACI 318 - ρ′

(e)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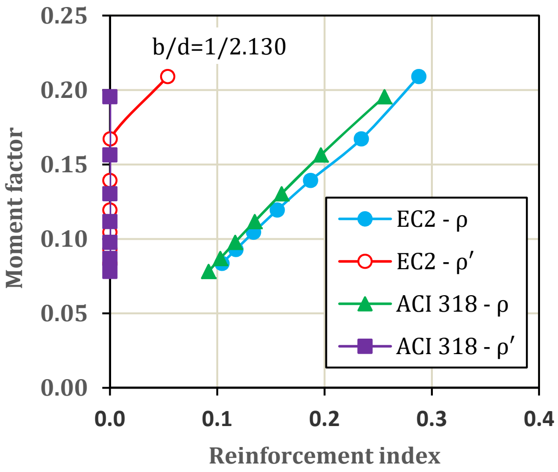
EC2 - ρ
EC2 - ρ′
ACI 318 - ρ
ACI 318 - ρ′

(f)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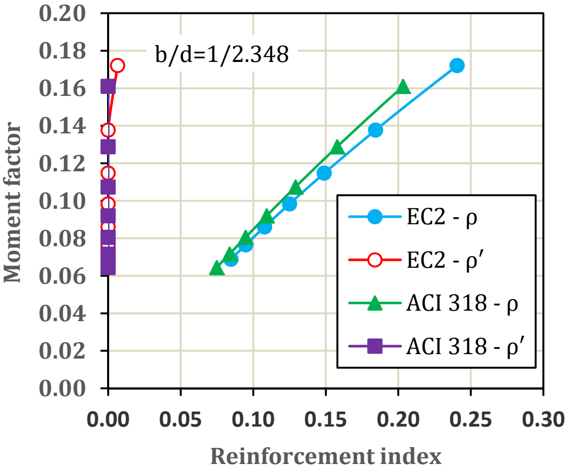
EC2 - ρ
EC2 - ρ′
ACI 318 - ρ
ACI 318 - ρ′

(g)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Reinforcement index
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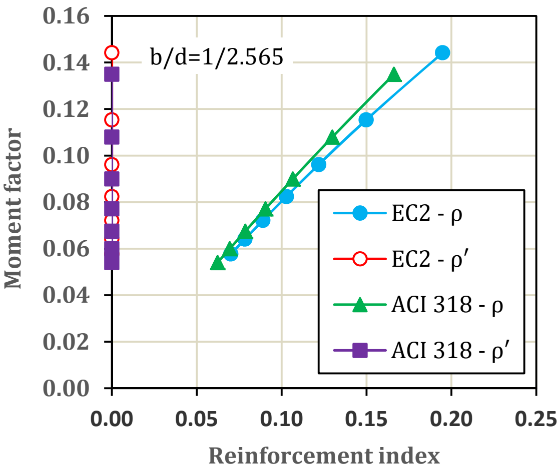
EC2 - ρ
EC2 - ρ′
ACI 318 - ρ
ACI 318 - ρ′

(h)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Reinforcement index
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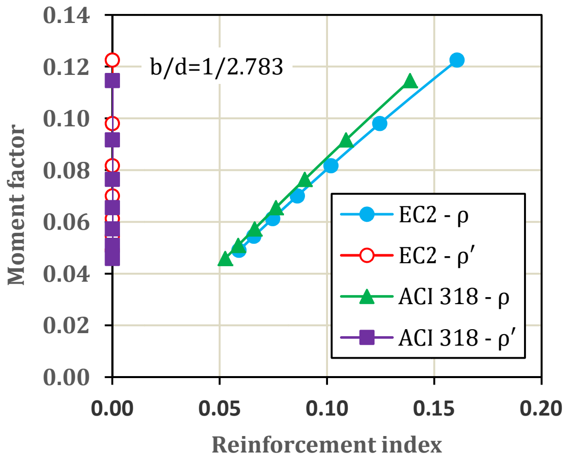
EC2 - ρ
EC2 - ρ′
ACI 318 - ρ
ACI 318 - ρ′

(i)



(j)

Fig. 1: Variation of moment factor with reinforcement index

In Fig.1 (a) for the shallowest beam (b=230 mm, h=250 mm), the reinforcement index for the tension reinforcement in EC2 varies from 2.142 to 0.841 for concrete cylinder strengths f_{ck} in the range 20–50 MPa. The equivalent values for ACI 318 vary from 1.758 to 0.692 for the same f_c' range of 20–50 MPa. Hence EC2 utilizes 21.5 % – 21.8 % more tensile reinforcement compared to ACI 318 for the shallowest beam. With regards to compression steel, the reinforcement index in EC2 ranges from 2.856 to 0.908 for f_{ck} in the range 20–50 MPa. The corresponding values for ACI 318 are 4.155 to 1.317. Hence ACI 318 utilizes 45.0 % – 45.5 % more compression reinforcement relative to EC2. It must be emphasized here however that the beam section 230 mm x 250 mm for a 6 m span simply supported beam would seldom be adopted in practice, from deflection concerns at least.

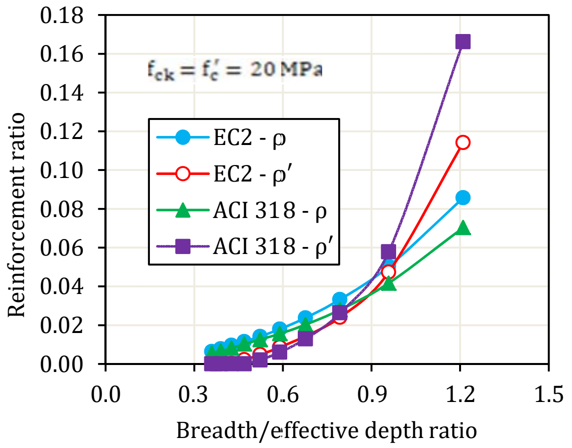
For the beam section 230 mm x 450 mm whose depth is very close to that recommended by both codes for a 6 m span beam, inspection of Fig. 1(e) reveals that the reinforcement index for tension steel in EC2 varies from 0.449 to 0.175 for f_{ck} in the 20–50 MPa range. The corresponding values for ACI 318 vary from 0.390 to 0.151. Again this demonstrates that the adoption of EC2 produces 15.1 % – 15.9 % more flexural tensile reinforcement in comparison to ACI 318. With reference to compression reinforcement and considering cylinder strengths in the range 20–30 MPa, the reinforcement index for EC2 ranged from 0.215 to 0.070, while the values for ACI 318 were from 0.151 to 0.005. This implies that use of EC2 would result in at least 42.4 % more reinforcement compared to ACI 318. It should be noted here that for this beam section, both codes require practically zero compression flexural reinforcement for a concrete cylinder strength in excess of 30 MPa.

In Fig. 1(j) for the deepest beam (b=230 mm, h=700 mm), the reinforcement index for the tension reinforcement in EC2 varies from 0.161 to 0.059 for f_{ck} in the range 20–50 MPa. The respective values for ACI 318 are in the range 0.139 to 0.053. Hence use of EC2 results in 11.3 % – 15.5 % more tension reinforcement compared to ACI 318. For such a beam section with b/d = 230/640 = 1/2.78, both codes quite reasonably require no flexural compression reinforcement.

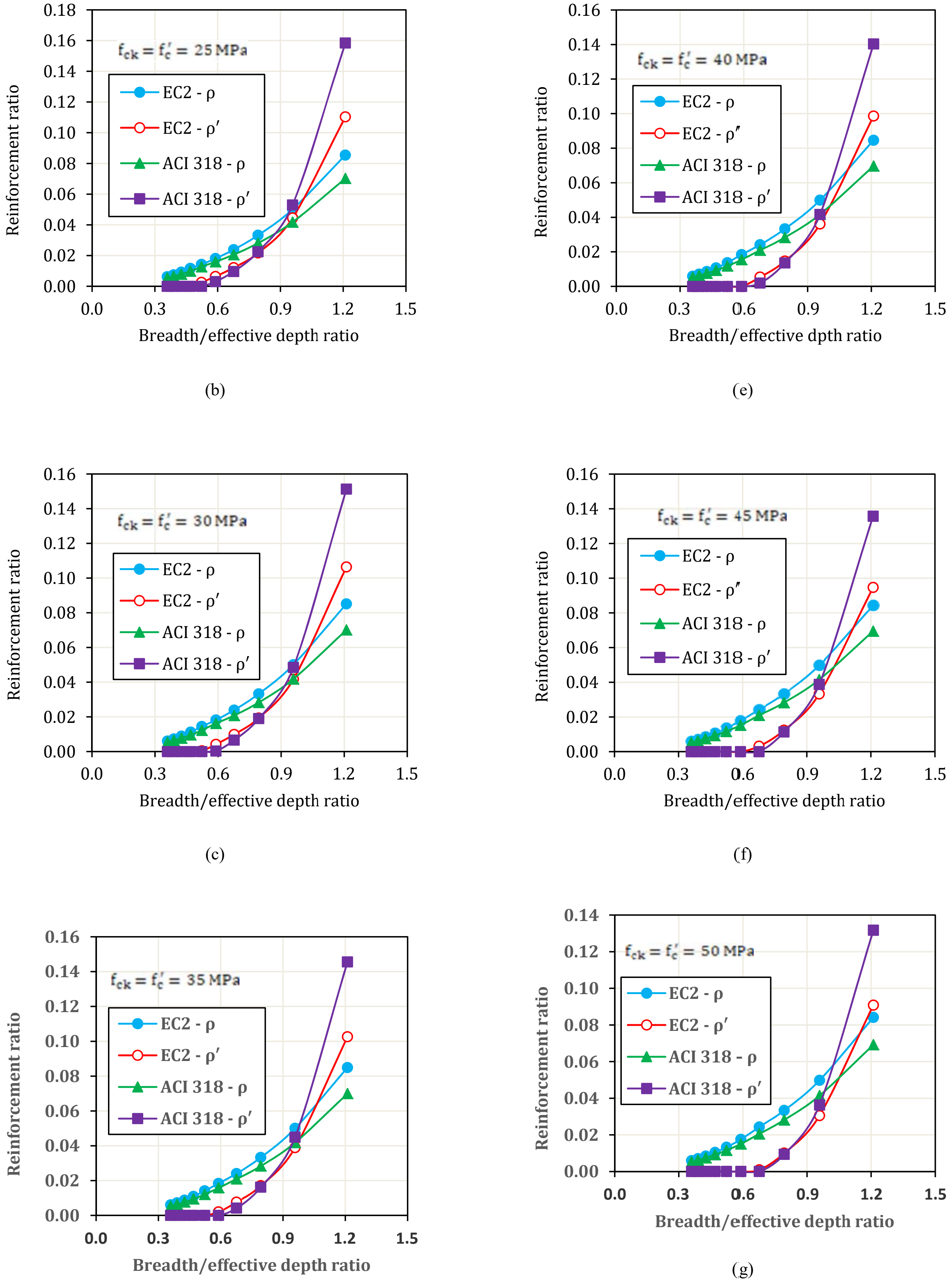
The above results demonstrate that for the beam sections that would be favoured or classed as economic designs, that is, those in the b/d range of 1/1.5 to 1/2.5, reference to Fig. 1(e)–(j) suggests that with respect to both tension and compression flexural reinforcements, EC2 requires more steel compared to ACI 318.These findings are in agreement with those of Hawileh et al. [12], and to an extent with the observations of Mohanty and Datta [16] and Bakhoum et al. [17]. However the relative values or differences between EC2 and ACI 318 in the present study vary somewhat, dependent on the beam aspect ratio or b/d and the concrete cylinder compressive strength f_c' or f_{ck}.

In Fig. 2(a)–(g), the variation of reinforcement ratios ρ or ρ′ with breadth/effective depth ratios b/d is shown for the different values of concrete compressive cylinder strengths, 20–50 MPa, used in the study. For comparative purposes, the results of EC2 and ACI 318 are shown alongside each other. From inspection it is obvious that the various figures are fairly similar, suggesting that the influence of concrete cylinder strengths might not be too significant.

In Fig. 2(a) with respect to concrete strength f_{ck} = 20 MPa and shallow beams (0.8 < b/d < 1.25), the EC2 code required on average about 20.5 % more tensile reinforcement than ACI 318. This difference appears to be approximately maintained for all f_{ck} values up to 50 MPa from inspection of Fig. 2(b)–(g). In the case of the more normal beams or those sections generally favoured as more economical (0.4 < b/d < 0.67), EC2 required an average of 15.6 % more tensile steel compared to ACI 318 for an f_{ck} value of 20 MPa. With respect to a f_{ck} value of 50 MPa, reference to Fig. 2(g) suggests that EC2 needs 20 % and 14.4 % more tensile reinforcement in contrast to ACI 318 for the cases of shallow and normal/economical beam sections respectively.



(a)



(b)

(e)

(c)

(f)

(d)

(g)

Fig. 2: Variation of reinforcement ratio with breadth/effective depth ratio

If attention is turned to flexural compression reinforcement however, for a low concrete strength f_{ck} = 20 MPa, Fig. 2(a) reveals that use of EC2 results in an average of 19.4 % less compression reinforcement for shallow beam sections in contrast to ACI 318. Examination of Fig. 2(b)–(g) suggest that this trend is maintained for all shallow sections regardless of concrete strength levels. For instance at f_{ck} = 50 MPa for shallow beams, EC2 requires on average 13.4 % less compression steel than ACI 318. In the case of beam sections classed as more normal/economical, the situation is reversed to some extent. For example from Fig. 2(a), EC2 requires an average of 63.3 % more compression reinforcement than ACI 318. It should be noted that this latter estimate is for a f_{ck} value of 20 MPa which is surely quite low in practical designs. For higher concrete strengths it becomes increasingly more difficult to make a comparative analysis in respect of flexural compression reinforcement, for in most cases investigated in the study, use of either EC2 or ACI 318 would result in practically zero flexural compression reinforcement for normal beams ($0.4 < b/d < 0.67$) in view of the larger effective depths being utilized.

While the above discussions have made a strong case for EC2 being considered less economical than ACI 318M-14 in terms of the amount of flexural tensile reinforcements required for practical design, it should be borne in mind herein that the study carried out was in respect of a simply supported beam with fixed characteristic dead and imposed loads. If various levels of dead and imposed loads were utilized, or more precisely if the ratio of these loads were varied, it could be expected that results different from those contained herein would be obtained. Additionally the present study focused on the span moments, quite naturally in a simply supported beam. It is suggested that very useful results could be obtained if for example a three-span continuous beam was studied. This exercise would yield information for support and span moments at the various critical locations. Hence it is recommended that additional studies along these lines be pursued in order to yield a more complete comparison of the flexural provisions of both codes.

IV. CONCLUSIONS

The work conducted in the present investigation sought to evaluate the differences between the flexural provisions for beams as contained in the two codes EC2 and ACI 318M-14 via a simplified comparative study. The latter involved an assessment of the amount of flexural compressive and tensile reinforcement required for a 6 m span simply supported beam subjected to fixed dead and imposed loadings. The work involved a parametric study in which the b/h or b/d ratio of the beam was varied to encompass the full range of design scenarios, from very shallow to narrow/deep beams. The concrete compressive cylinder strength f_c' or f_{ck} covered the range 20–50 MPa. Based on the results of the investigation carried out, the following conclusions were drawn.

1. With respect to flexural tensile reinforcement for very shallow beams of low compressive strengths, EC2 required an average of 20.5 % more reinforcement compared to ACI 318M-14. However for more normal or narrow/deep beams of similar low compressive strengths, EC2 needed 15.6 % more steel in contrast to ACI 318M-14.
2. With reference to flexural tensile reinforcement in beams of much higher compressive strengths, EC2 warrants 20 % and 14.4 % more reinforcement in comparison to ACI 318M-14, for very shallow and narrow/deep beams respectively.
3. Concerning flexural compression steel for beams of low concrete compressive strengths EC2 demands 19.4 % less and 63.3 % more reinforcement as opposed to ACI 318M-14, for very shallow and narrow/deep beams respectively.
4. Regarding flexural compression steel in beams of much higher concrete strengths, EC2 requires an average of 13.4 % less reinforcement for very shallow beams in contrast to ACI 318M-14.
5. In general for beams in the economic range and well beyond ($0.4 < b/d < 1.25$), flexural tensile requirements of EC2 are consistently conservative in comparison to ACI 318M-14 for concrete compressive cylinder strengths in the range 20–50 MPa.
6. Since the present study dealt exclusively with provision of flexural reinforcement at mid-span in simply supported beams, it is recommended that additional investigation be carried out utilizing for example a three-span continuous beam in order to cater for both support and span moments. While the range of concrete compressive cylinder strengths could be retained as per the current study, various ratios of live loads to dead loads should be incorporated, say from 1/4 to 4.0, in the proposed investigation. This would enable a more complete comparison between the flexural requirements of EC2 and ACI 318M-14 to be effected.

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