An Efficient Parameter For Prediction Of The Nonlinear Lateral Behavior Of Deformation-Controlled RC Columns

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SUMMARY:
This paper discusses about the affective parameters in determining the capacity curve of reinforced concrete columns with flexural or flexure-shear failure modes. For this aim, results of the lateral cyclic tests on 54 RC columns with one of these failure modes are studied. An efficient confinement index is proposed that considers all of the important parameters affecting the lateral behavior and shows excellent correlation with the experimentally obtained nonlinear lateral behavior of the studied columns. The general form of the backbone curve of the displacement-controlled structural elements in ASCE 41 is defined by using two key displacements "a" and "b". By using the proposed confinement index and based on the results of studied columns, a table is presented as an alternative to the tables presented in the ASCE4106 standard for prediction of the lateral nonlinear behavior of RC columns.

Keywords: RC column, confinement, earthquake, standard

1. INTRODUCTION

Reasonable determination of the seismic performance of a structure requires true approximation of the lateral force-displacement curve of its elements. The conventional models for modeling of the nonlinear behavior of structural elements simplify the nonlinear behavior by a multilinear curve. One of such models has been utilized in ASCE 4106 for defining the nonlinear lateral behavior of various structural elements for application in seismic rehabilitation of existing buildings. In this standard, the structural elements are divided into either force or displacement controlled based on their lateral force-displacement curves. The lateral capacity curves of deformation controlled elements consist of an elastic range followed by a plastic range which in turn includes a strain hardening or softening and a strength- degraded range. The values required to obtain the capacity curves of various structural elements are tabulated in the standard based on the parameters that are assumed to affect their nonlinear behavior.

Among various characteristics of the nonlinear behaviour of reinforced concrete columns including stiffness, yield and ultimate strength and ductility, the latter is the most important in determining the performance level of a column in a severe earthquake, on which this study focuses. Definition of the ductility of a structural element depends on the definition of the ultimate point of its performance. There are two ultimate points for an element including the points of loss of the lateral and axial capacity. In this paper, the parameters that are used by various versions of the seismic rehabilitation standard (including FEMA273, FEMA 356, ASCE41-06 and update to ASCE41-06) to determine the ultimate points of RC columns that fail in a flexural mode and their changes are discussed. Experimental results of the lateral behaviour of 54 large-scale RC columns are used to compare their ultimate points with those predicted by these documents. It is shown that the main reason for the inappropriateness of these documents in accurate prediction of the ductility of the flexure-critical RC columns is missing to explicitly and properly take the level of confinement of the column into account. A confinement index is presented in which the two missing parameters of the yield strength and the arrangement of the transverse reinforcements are taken into account. This index was successfully applied in predicting the lateral behaviour of the tested columns.

2. THE GENERAL FORM OF THE BACKBONE CURVE OF DISPLACEMENT-CONTROLLED RC COLUMNS

The general forms of the lateral force-displacement behaviour of displacement-controlled structural elements, as introduced by ASCE 41-06, are shown in figure 1. The Type 1 curve depicted in Figure 1 is representative of ductile behaviour where there is an elastic range (point 0 to point 1 on the curve) followed by a plastic range (points 1 to 3) with non-negligible residual strength and ability to support gravity loads at point 3. The Type 2 curve depicted in Figure 1 is representative of ductile behaviour where there is an elastic range (point 0 to point 1 on the curve) and a plastic range (points 1 to 2) followed by loss of strength and loss of ability to support gravity loads beyond point 2. The definition of the type 2 curve has been changed in the updated to ASCE 41-06 as shown in figure 1. As shown in this figure, in the update to ASCE 41-06, for the type 2 behaviour it has been assumed that at point 3 the axial capacity is still preserved. It is obvious from figure 1 that the main parameters that define the backbone curve of these elements are values of the parameters "a" and "b" that will be called *the displacement parameters of the backbone curve* hereafter.

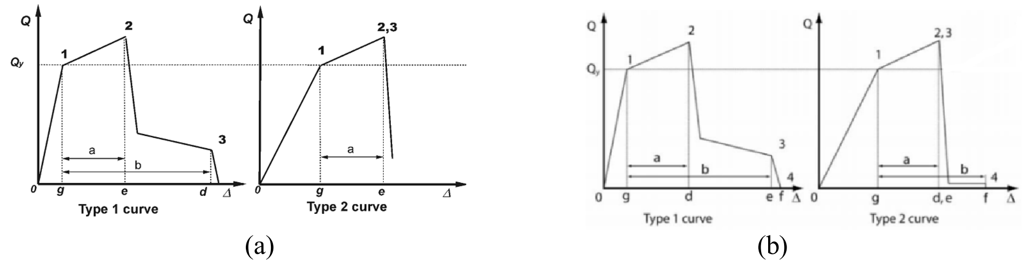

Figure 1. A comparison between the general force-displacement curves of a) ASCE41-06 and b) its update

The procedures proposed in the update to ASCE 41-06 for obtaining the backbone curve differs from its previous versions. According to the update to ASCE 41-06, a smooth backbone curve is drawn through each point of peak displacement during the first cycle of each increment of loading (or deformation). In contrast, in FEMA 273 , 356 and ASCE 41-06, the backbone curve is drawn through the intersection of the first cycle curve for the (i)th deformation step with the second cycle curve of the (i-1)th deformation step, for all i steps. This difference is shown in figure 2 for one of the studied columns.

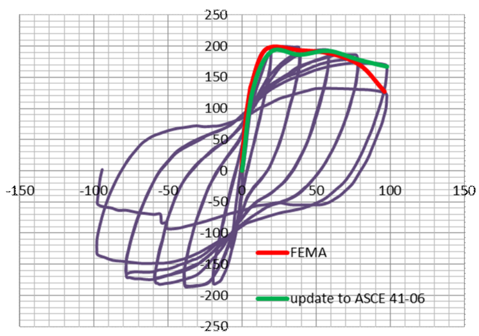

Figure 2. A comparison between the backbone curves obtained according to update to ASCE 41-06 and its former versions for column specimen

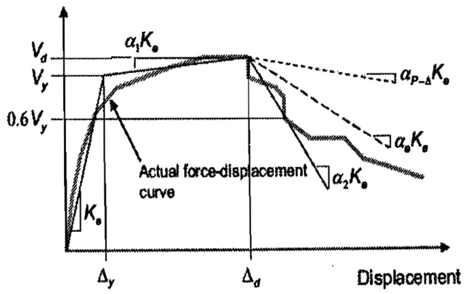

Figure 3. Idealizing the force-displacement curve

3. THE FACTORS THAT DETERMINE THE DISPLACEMENT PARAMETERS OF THE BACKBONE CURVE PARAMETERS IN ASCE41-06

In FEMA 273, 356 and ASCE 41-06, the RC columns are divided into four groups of flexure controlled, shear controlled, lap-splice slippage controlled and columns under high axial load. They assume that the values of the parameters a and b that define the backbone curve of RC columns are dependent on two parameters of $\frac{P}{A_g f_c'}$ and $\frac{V}{b_w d\sqrt{f_c'}}$ and also the spacing and details of the hoops, in which p and V are the existing axial and lateral loads, respectively.
In these parameters, bw , d and Ag are width, depth and area of column section, respectively and f'c is the concrete compressive strength.

On the other hand, in the update to ASCE 41-06 the column behavior is divided into four major modes of flexural (condition i), shear-flexural (condition ii), shear (condition iii) and slippage of lap-splice (condition iv). This classification is performed based on the ratio of $\frac{V_P}{V_n}$, in which Vp and Vn are the shear demand due to the formation of the plastic hinge and the nominal shear strength, respectively.
The values of the parameters a and b for each condition has been assumed to be dependent on three parameters including $\frac{P}{A_g f_c'}$, $\frac{V}{b_w d\sqrt{f_c'}}$ and $\rho = \frac{A_v}{b_w s}$, in which Av and s are the area and spacing between transverse reinforcements, respectively.

It seems that two major parameters have been missed to account for in all of these documents. The missed parameters are the yield strength and the arrangement of the transverse reinforcements that determine the level of confinement of core of the RC columns. In this study, attempt has been made to include this parameter in determining the values of parameters a and b of RC columns.

4. THE UNIFORM PROCEDURE FOR DETERMINATION OF THE BACKBONE CURVE PARAMETERS FROM EXPERIMENTAL DATA

Results of the lateral tests on 41 reinforced concrete columns, which were reported in the PEER database, are used to study their values of the parameter "a". These column specimens are summarized in table 2. In accordance with the classification of the update to ASCE 41-06, these columns fail in a flexural mode (condition i). The calculated ratio of $\frac{V_P}{V_n}$ for these columns are between 0.6 and 1 and their details conform with ACI and they have 135° hooks. Test setups of the selected columns have been so designated to include the P-Δ effect.
On the other hand, derivation of the value of parameter "b" requires the displacement at which the column ability to support the gravity load has been lost. Very few studies have reported such a loss. Only 13 column specimens were found in the PEER database and applied, in which the lateral displacement corresponding to this critical point have been reported. The values of the parameter "b" of these columns were calculated from these tests.

Two backbone curves were obtained for each one of the studied columns based on the two aforementioned procedures. The lateral force-displacement hysteretic curves of these columns were used to obtain their backbone curves. The obtained backbone curves were then approximated by a series of linear segments conforming to one of the types indicated in figure 1 and the parameter "a" and "b" were obtained. So as to eliminate any undesirable non-uniformity among the test data in determination of these parameters from the backbone curves, the procedure proposed in ASCE 41-06 for idealizing the force-displacement curve of a structure was utilized. This procedure is schematically shown in figure 3.

The abovementioned procedures of FEMA356 and update to ASCE41-06 were used in obtaining the values of parameter "a" (ameasured). The ratios of experimentally obtained values of "a" to those predicted by the two documents (apredicted) are drawn in figure 4. These ratios are also summarized in table 2. As can be seen in figure 4, the predicted values of FEMA356 are too conservative. Even for one of the columns, the experimentally obtained value of "a" is 23 times its predicted value by FEMA356. This seems to be because of the following reasons:

i) The procedure of FEMA 356 in obtaining the backbone curve is too conservative, resulting in smaller ultimate displacement.
ii) More safety margin has been considered for the predicted values of the parameter a.
iii) Inappropriate classification of the columns and determining parameters

On the other hand the values predicted by the update to ASCE 41-06 give better estimations of the parameter "a". As shown in figure 4, the maximum ratio of the experimentally obtained value of parameter "a" to that predicted by the update to ASCE 41-06 is 4.7 that shows less underestimation in comparison with FEMA 356.

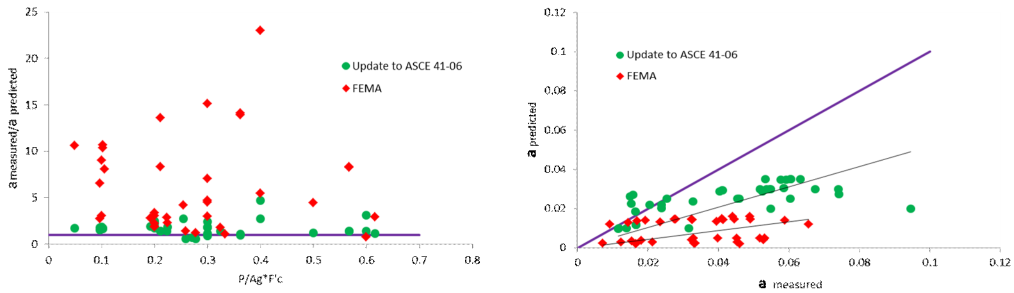

Figure 4. A comparison between the ratios of the measured values of the parameter "a" to that predicted by the update to ASCE 41-06 and FEMA356

5. PROPOSED DETERMINING FACTOR FOR FLEXURE-CRITICAL COLUMNS

As mentioned before, the parameter $\rho = \frac{A_v}{b_w s}$ (that was applied by the update to ASCE 41-06 in determining the values of the parameters a and b of the lateral behavior of RC columns) does not seem to rationally predict the level of available confinement (that is the main determining parameter in the behavior of flexure controlled columns). So as to obtain a better measure of the existing confinement level of a RC column, the following confinement index was applied.

$$\frac{f_{le}}{f'_{co}} = K_e \frac{\rho . f_{yh}}{2 f'_{co}} \tag{5.1}$$

In which f'_{co} is the strength of plain concrete and f_{le} is the confinement induced effective lateral pressure at the point of peak stress of confined concrete. The geometrical effectiveness coefficient Ke was introduced and applied by Sheikh and Uzumeri (1982), Mander et al. (1988) and Eurocode (1998) as the ratio between the effectively confined area to the gross sectional area of column.[1], [2], [3] This coefficient reflects the geometrical effectiveness of the longitudinal and transverse reinforcement in confining the concrete and depends on the shape of section and arrangement and spacing of transverse reinforcements. In fact, there are two distinctive effectiveness coefficients due to the arching actions between the rebars in section and height of a RC column. Therefore, the column geometrical effectiveness coefficient is the product of these coefficients, $K_e = K_{section}.K_{height}$.

Among several relations that have been proposed for the effectiveness coefficient (that some of them have been reviewed by Moghaddam et al. 2010), those proposed by EC8 were applied, that are as follows:

$$K_{,height} = \left(1 - \frac{s'}{2d_c}\right)^2 \tag{5.2}$$

$$K_{,section} = 1 - \frac{\sum w_i^2}{6D_xD_y} \tag{5.3}$$

In which s' is the clear spacing between transverse reinforcements, dc is the diameter of the confined core, wi is the distance between laterally restrained longitudinal reinforcements and Dx and Dy are the dimensions of the column section.

This confinement index was used as the determining parameter for predicting the parameters a and b of the tested columns of the database. This index seems to give better estimation of the confinement level because (in contrast to the parameter ρ that was used in the update to ASCE41-06) it takes the yield strength and configuration of the hoops into account. The correlation between the test data and the applied determining parameter of the update to ASCE41-06 (ρ) as well as the proposed index of this study can be observed in figure 5. In this figure, on the basis of the level of the applied axial load, the studied specimens are divided into three groups. It is obvious that the experimentally obtained values of the parameter "a" show more strong correlation with the proposed index than the confinement volumetric ratio (ρ). This is specially illuminated in this figure by comparing some specimens that their transverse reinforcements have the same volumetric ratio but (due to different values of their yield strength or configuration) have achieved distinctive values of the parameter "a". As an example, the advantage of this index can be observed when comparing two similar column specimens tested by Muguruma et al. 1989 in table 2.[4] The only difference between the two specimens was their different values of the yield strength of transverse reinforcements, that was 328.4 and 792.3 MPa for specimens AL-1 and AH-1, respectively. It is observed that although the volumetric ratio ρ for both of these specimens are the same (and therefore the same value will be obtained for the parameter "a" by using the update to ASCE 41-06) but different displacement capacities have been recorded for these specimens during the tests. In contrast, the different values of the proposed confinement index of these two specimens can explain the reason of the difference.

The correlation between the two determining parameters of ρ and $\frac{f_{le}}{f'_{co}}$ and the measured values of the parameter "a" are compared in figure 5. The results of column specimens are divided into three groups on the basis of the level of the applied axial load. It can be observed that the proposed index shows a stronger linear relationship with the measured values of the parameter "a". In addition, the specimens that their transverse reinforcements have the same volumetric ratio but have achieved different values of "a" have been illuminated in this figures by oval shapes. This implies the advantage of the proposed index that can explain the higher values of achieved "a".

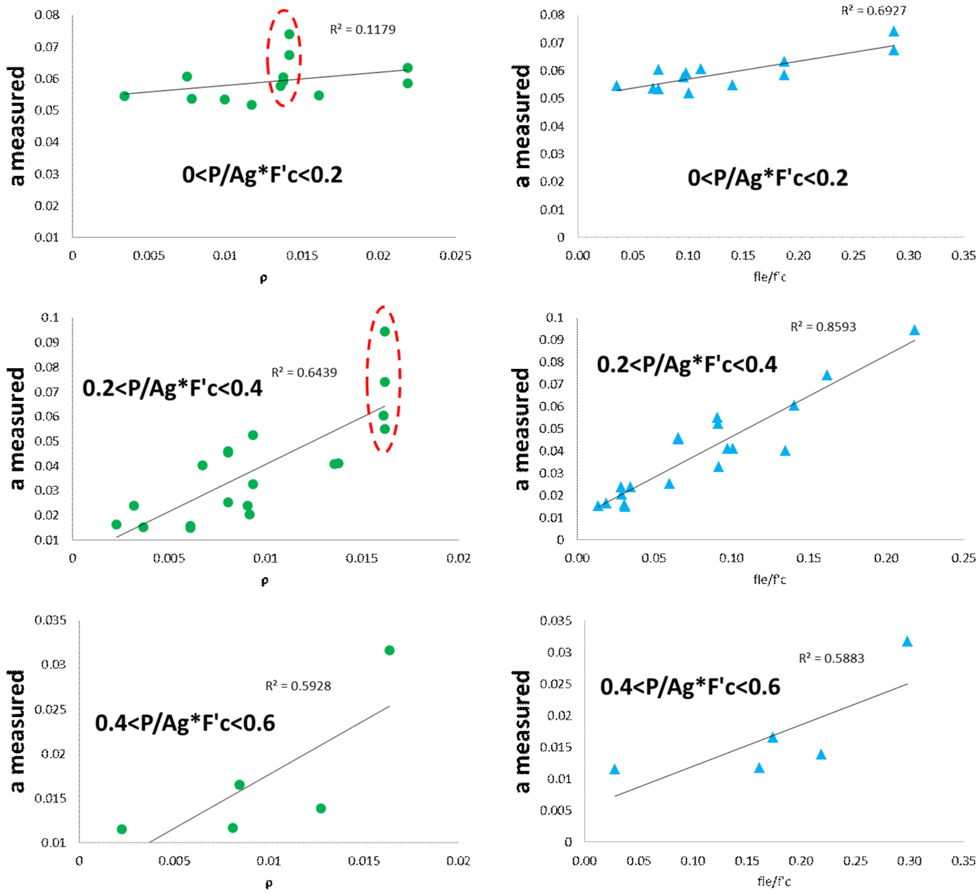

Figure 5. Comparing the correlations between the measured values of the parameter "a" with a) The volumetric ratio of confinement (i.e. the determining parameter of the update to ASCE) and b) The effective confinement index (proposed determining parameter)

6. PROPOSING THE ALTERNATIVE VALUES OF DISPLACEMENT PARAMETERS OF THE BACKBONE CURVE

The proposed confinement index was used as the determining parameter for predicting values of the displacement capacity of RC columns. These proposed values are summarized in table 1. As shown in figure 5, this index showed a reasonable ability to predict the trend of variations of the parameter "a" of studied columns. Therefore, the values of the parameters "a" of the abovementioned 41 specimens as well as the measured values of the parameter "b" of the aforementioned 13 specimens were used to propose the values for the parameters "a" and "b" on the basis of the proposed confinement index and the level of axial load as shown in table 1. These values were so proposed that show the best fit to the experimental data and the exceedance probability of the experimental values to the predicted ones would be less than 20% for "a" and 10% for "b" due to the more catastrophic nature of the loss of axial load carrying capacity.

Table 1. The proposed table for prediction of the displacement parameters of the backbone curve

$\frac{P}{A_g f_c'}$	$\alpha \times \omega_w$	a	b
≤ 0.1	≥ 0.15	0.059	0.075
≥ 0.5	≥ 0.15	0.015	0.03
≤ 0.1	≤ 0.05	0.035	0.04
≥ 0.5	≤ 0.05	0.009	0.02

7. COMPARISON OF THE PROPOSED TABLE WITH THE UPDATE TO ASCE41-06

The proposed table was used to predict the values of the parameters "a"of the 41 studied columns. These predicted values are summarized and compared with experimentally obtained values in table 2. The same task was conducted by using the tables presented in the update to ASCE 41-06. Similarly, the predicted values of parameter "b" of the 13 studied columns (that their loss of the axial load carrying capacity) by using the proposed table (table1) are compared with experimental values and the values predicted by the update to ASCE 41-06 in table 3. In addition, the ratios of the experimentally obtained values of the parameter "a" for the 41 studied specimens to those predicted by the proposed table as well as the update to ASCE 41-06 are drawn in figure 6. It can be seen in this figure that the proposed table has given closer values to the experimental ones than the table of ASCE 41-06. Similar comparison has been made in figure 6 for the values of the parameter "b". A comparison between the predicted values of the two parameter "a" and "b" in Tables 2 and 3 by using the proposed table with those predicted by the update to ASCE 41-06 can obviously shows the better ability of the proposed table. While the maximum ratio of the measured to predicted values by FEMA356 and the update to ASCE 41-06 for the parameter "a" are 23 for FEMA 356 and 4.7 for the update to ASCE 41-06, this ratio is 3.6 when using the proposed table. This shows more rational prediction of the displacement capacity of RC columns by using the proposed table.

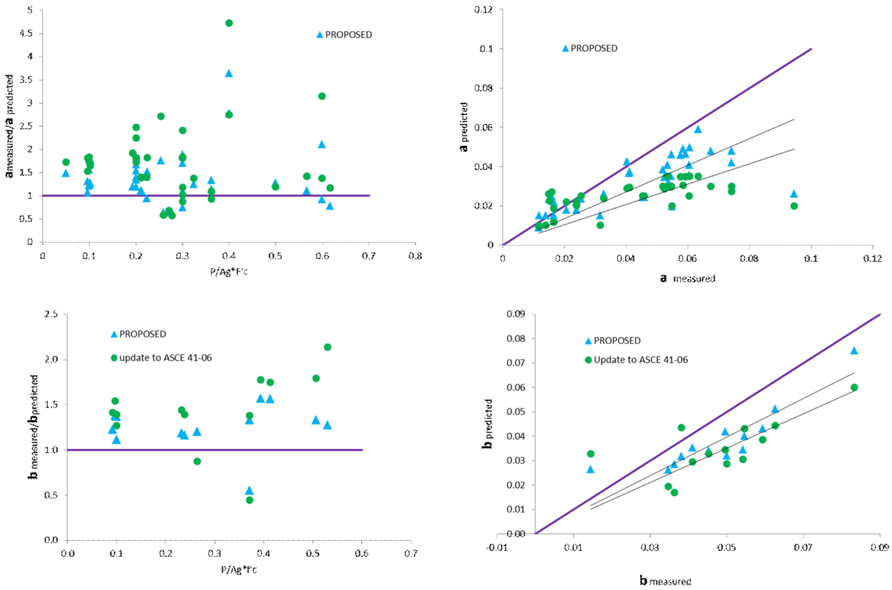

Figure 6. The ratio of the measured values of the parameters "a" and "b" to those predicted by the proposed table for the studied columns

Table 2. The measured and predicted values of the displacement parameter “a” of the studied columns

				FEMA356	*Update to ASCE 41-06*	*FEMA356*	*Update to ASCE 41-06*	*PROPOSED*	*FEMA356*	*Update to ASCE 41-06*	*PROPOSED*
Specimen Name	$\frac{P}{A_g f_c^{'}}$	$\frac{A_v}{b_w s}$	$\frac{f_{le}}{f_{co}^{'}}$	*a measured*	*a measured*	*a predicted*	*a predicted*	*a predicted*	$\frac{a(measured)}{a(predicted)}$	$\frac{a(measured)}{a(predicted)}$	$\frac{a(measured)}{a(predicted)}$
Matamoros,1999,C10-05S	0.0495	0.0137	0.0735	0.0532	0.0603	0.0050	0.0350	0.0406	10.6341	1.7239	1.4849
Xiao,1998,HC4-8L16-T10-0.1P	0.0962	0.0219	0.1870	0.0440	0.0633	0.0160	0.0350	0.0590	2.7473	1.8088	1.0730
Xiao,1998,HC4-8L16-T6-0.1P	0.0962	0.0099	0.0735	0.0329	0.0534	0.0050	0.0350	0.0406	6.5815	1.5246	1.3129
Soesianawati,1986,n1	0.1000	0.0034	0.0379	0.0452	0.0546	0.0050	0.0298	0.0350	9.0490	1.8314	1.5588
Tanaka,1990,n6	0.1000	0.0075	0.1113	0.0490	0.0606	0.0160	0.0350	0.0497	3.0608	1.7309	1.2184
Matamoros,1999,C10-10N	0.1020	0.0137	0.0980	0.0518	0.0592	0.0050	0.0349	0.0463	10.3941	1.6964	1.2777
Matamoros,1999,C10-10S	0.1020	0.0136	0.0957	0.0531	0.0576	0.0050	0.0349	0.0458	10.6559	1.6512	1.2586
Kanda,1988,85STC-1	0.1055	0.0038	0.0373	0.0399		0.0049	0.0303	0.0346	8.0626		
Xiao,1998,HC4-8L16-T10-0.2P	0.1925	0.0219	0.1870	0.0409	0.0585	0.0148	0.0304	0.0488	2.7717	1.9252	1.1977
Tanaka,1990,n2	0.2000	0.0141	0.2864	0.0491	0.0741	0.0147	0.0300	0.0480	3.3497	2.4696	1.5434
Tanaka,1990,n4	0.2000	0.0141	0.2864	0.0445	0.0674	0.0147	0.0300	0.0480	3.0351	2.2460	1.4037
Xiao,2002,FHC1-0.2	0.2000	0.0117	0.1010		0.0518		0.0300	0.0384		1.7267	1.3476
Xiao,2002,FHC6-0.2	0.2000	0.0078	0.0683	0.0324	0.0536	0.0147	0.0300	0.0321	2.2097	1.7874	1.6723
Galeota,1996.CB1	0.2000	0.0161	0.1401	0.0275	0.0547	0.0147	0.0300	0.0461	1.8739	1.8246	1.1883
Galeota,1996.CB2	0.2000	0.0161	0.1401	0.0279		0.0147	0.0300	0.0461	1.8992		
Matamoros,1999,C10-20N	0.2108	0.0137	0.1008	0.0324	0.0411	0.0039	0.0295	0.0375	8.3274	1.3962	1.0979
Matamoros,1999,C10-20S	0.2108	0.0136	0.0970	0.0529	0.0410	0.0039	0.0295	0.0367	13.5841	1.3901	1.1149
Zahn,1986,n7	0.2231	0.0067	0.1346	0.0413	0.0402	0.0144	0.0288	0.0426	2.8768	1.3953	0.9444
Xiao,2002,FHC3-0.22	0.2247	0.0093	0.0912	0.0326	0.0524	0.0143	0.0288	0.0345	2.2761	1.8222	1.5203
Muguruma,1989,BH-1	0.2539	0.0162	0.1615	0.0589	0.0742	0.0139	0.0273	0.0421	4.2228	2.7156	1.7624
Atalay,1975,n9	0.2586	0.0061	0.0304	0.0192	0.0158	0.0139	0.0271	0.0247	1.3849	0.5847	0.6410
Atalay,1975,n12	0.2708	0.0037	0.0134		0.0152		0.0224	0.0239		0.6804	0.6371
Atalay,1975,n11	0.2778	0.0061	0.0310	0.0169	0.0149	0.0136	0.0261	0.0234	1.2406	0.5701	0.6349
Soesianawati,1986,n3	0.3000	0.0032	0.0345	0.0154	0.0238	0.0034	0.0202	0.0220	4.4865	1.1796	1.0826
Soesianawati,1986,n4	0.3000	0.0023	0.0187	0.0182	0.0164	0.0039	0.0186	0.0220	4.7107	0.8824	0.7474
Galeota,1996.BA2	0.3000	0.0080	0.0599		0.0254		0.0250	0.0235		1.0142	1.0797
Galeota,1996.BB4	0.3000	0.0080	0.0653	0.0453	0.0459	0.0030	0.0250	0.0243	15.1111	1.8351	1.8882
Galeota,1996.BB4B	0.3000	0.0080	0.0653	0.0212	0.0454	0.0030	0.0250	0.0243	7.0795	1.8140	1.8666
Galeota,1996.CB3	0.3000	0.0161	0.1401	0.0395	0.0604	0.0133	0.0250	0.0355	2.9630	2.4142	1.6997
Xiao,2002,FHC4-0.33	0.3244	0.0093	0.0914	0.0234	0.0328	0.0130	0.0238	0.0262	1.8013	1.3776	1.2517
Xiao,2002,FHC2-0.34	0.3326	0.0117	0.1042	0.0144		0.0129	0.0234	0.0272	1.1150		
Matamoros,1999,C5-40N	0.3624	0.0092	0.0290	0.0335	0.0205	0.0024	0.0219	0.0179	14.1031	0.9373	1.1429
Matamoros,1999,C5-40S	0.3624	0.0090	0.0284	0.0331	0.0238	0.0024	0.0219	0.0179	13.9286	1.0899	1.3290
Muguruma,1989,AL-1	0.3999	0.0162	0.0905	0.0460	0.0549	0.0020	0.0200	0.0198	22.9903	2.7436	2.7784
Muguruma,1989,AH-1	0.3999	0.0162	0.2182	0.0657	0.0945	0.0120	0.0200	0.0260	5.4725	4.7238	3.6333
Watson,1989,n6	0.5000	0.0022	0.0276	0.0124	0.0115	0.0028	0.0097	0.0090	4.4802	1.1895	1.2810
Bechtoula,2002,L1D60	0.5669	0.0084	0.1737	0.0166	0.0165	0.0020	0.0117	0.0150	8.3029	1.4191	1.1027
Bechtoula,2002,L1N60	0.5669	0.0084	0.1737	0.0166	0.0165	0.0020	0.0117	0.0150	8.2754	1.4190	1.1026
Sugano,1996,UC15H	0.5991	0.0127	0.2182	0.0091	0.0139	0.0120	0.0100	0.0150	0.7624	1.3802	0.9241
Sugano,1996,UC20H	0.5991	0.0163	0.2976		0.0316		0.0100	0.0150		3.1495	2.1089
Ono,1989,CA060C	0.6163	0.0081	0.1611	0.0071	0.0117	0.0024	0.0100	0.0150	2.9026	1.1693	0.7796

Table 3. The measured and predicted values of the parameter “b” of the studied columns

Specimen Name	$\frac{P}{A_g f_c^{'}}$	$\frac{A_v}{b_w s}$	$\frac{f_{le}}{f_{co}^{'}}$	b measured	Update to ASCE 41-06 b predicted	PROPOSED b predicted	Update to ASCE 41-06 $\frac{b(measured)}{b(predicted)}$	PROPOSED $\frac{b(measured)}{b(predicted)}$
Wehbe et al. ,1998, B1	0.0923	0.0036	0.0820	0.0627	0.0443	0.0512	1.4142	1.2239
Wehbe et al., 1998, A1	0.0975	0.0027	0.0587	0.0594	0.0386	0.0430	1.5394	1.3803
Xiao and Martirossyan, 1998, HC4-8L19-T10-0.1P	0.0997	0.0219	0.2423	0.0833	0.0600	0.0750	1.3881	1.1105
Soesianawati et al., 1986, No. 1	0.1000	0.0034	0.0379	0.0547	0.0431	0.0400	1.2688	1.3663
Wehbe et al., 1998, B2	0.2324	0.0036	0.0820	0.0496	0.0344	0.0419	1.4413	1.1833
Wehbe et al. ,1998, A2	0.2387	0.0027	0.0587	0.0411	0.0295	0.0353	1.3930	1.1631
Paultre & Legeron, 2000, No. 10013025	0.2641	0.0076	0.0327	0.0381	0.0436	0.0318	0.8749	1.1995
Paultre & Legeron, 2000, No. 10013040	0.3710	0.0076	0.0328	0.0146	0.0329	0.0264	0.4423	0.5501
Paultre et al., 2001, No. 1008040	0.3714	0.0087	0.0927	0.0453	0.0329	0.0341	1.3786	1.3269
Paultre & Legeron,, 2000, No. 1006040	0.3941	0.0164	0.1057	0.0543	0.0306	0.0345	1.7734	1.5702
Paultre et al., 2001, No. 1206040	0.4135	0.0164	0.0996	0.0500	0.0287	0.0320	1.7465	1.5655
Paultre et al., 2001, No. 1006052	0.5060	0.0164	0.1117	0.0348	0.0194	0.0262	1.7930	1.3291
Paultre et al., 2001, No. 1005552	0.5298	0.0127	0.1356	0.0364	0.0170	0.0286	2.1360	1.2729

8. CONCLUSION

The nonlinear force-displacement behaviour of RC columns are defined by using the two parameters that are named “a” and “b” in the seismic rehabilitation standards, that correspond to the displacements at which the lateral and axial capacity of the column is lost. The values proposed in the current standards for these parameters depend on the volumetric ratio of confinement for columns that fail in flexure. An effective confinement index was proposed that also takes the yield strength and the arrangement of the transverse reinforcements into account. It is shown that there is a stronger correlation between the experimentally obtained values of the parameter “a” of several RC columns and the proposed confinement index than the volumetric ratio of confinement, i.e. the determining parameter of the update to ASCE 41-06. Results of 41 and 13 RC columns were used to obtain “a” and “b”, respectively. A table was presented that predicts the values of these two parameters based on the proposed confinement index. It is shown that the proposed table predicts more accurate values for the parameters “a” and “b” than the update to ASCE 41-06 and FEMA356.

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