CUMBIA—Set of Matlab/Octave codes for the analysis of reinforced concrete members – for Practice version

User Guide

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DISCLAIMER

There are **no warranties**, explicit or implicit, that the codes contained in this collection are free of error, or are consistent with any particular standard of accuracy, or that they will meet your requirements for any particular application. They should not be relied on for any purpose where incorrect results could result in loss of property or personal injury. If you do use the codes for any such purpose it is at your own risk. The authors disclaim all liability of any kind, direct or consequential, resulting from your use of these codes.

CUMBIA-for-Practice is available from https://github.com/ArsalanNiroomandi/CUMBIA-for-Practice

If you use CUMBIA-for-Practice to produce scientific articles, please cite as:

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1. INTRODUCTION

CUMBIA is a set of Matlab/Octave codes to perform monotonic moment-curvature analysis and force-displacement response of reinforced concrete (RC) members of rectangular or circular sections written by Luis Montejo. This version of CUMBIA is following the CUMBIARECT and CUMBIACIR codes and is specifically modified for assessing and designing RC beams and columns in buildings with large number of elements. Refer to the original CUMBIA Manual for more information regarding the theories behind the codes. In this version of CUMBIA, the input file will be read from an excel file for each beam or column. Then, all the elements will be analysed at the same time by another code, CUMBIA_practice_exe. Some output parameters have been introduced in the code. However, depends on the project, the engineer can add other output parameters as well.

If you do not have access to Matlab, you can use Octave which is a free software that can run Matlab codes as well. Octave can be downloaded from the link below:

https://www.gnu.org/software/octave/download

2. INPUT FILE

Two examples of excel input files for rectangular and circular columns are provided. Each tab of the excel file is discussed in the following sub-sections.

2.1. Description

In the “Description” tab of the input excel file, each input parameter is introduced.

2.2. Sections

In the “Sections” tab, the main characteristics of each unique column are defined. In the excel input file example for rectangular columns, since in this building there was only one hoop around the longitudinal bars, and the columns were square, wi is defined as H-2clb-d_b. If this is not the case, wi should be calculated according to the figure shown in the “Description” tab from Mander, Priestley and Park (1988). It should be noted that wi can be calculated as an average value or a vector. See the original Manual of CUMBIA for more information. For rectangular columns, two separate input files are required for the strong and weak axis. In the case of RC beams, since often the top and bottom reinforcement are different, two separate input excel files may need to be built for the negative and positive moments. If the behaviour of the beam or column is controlled by insufficient lap splice or longitudinal bars development length, the maximum tension stress that can be developed in the bars, f_{splice}, can be determined according to Equation (1) from ASCE41-17 (2017) and Section C5 of the NZ seismic assessment guidelines (NZSEE 2017). f_{splice} should replace f_y in the “input” tab. It should be noted that the names used in this tab should match the section names used in the analysis software.

$$f_{splice} = 1.25\left(L_{d,prov}/L_d\right)^{2/3} f_y \leq f_y \tag{1}$$

2.3. Frame Assigns

The section name used in the analysis software and the length of the elements are defined in the “Frame Assigns” tab. These can be directly exported from the analysis software such as ETABS.

2.4. Element Forces – Columns

The axial load of each column is defined in the "Element Forces – Columns" tab. In this example, the axial load of each column is determined based on the gravity load case (D+0.3L). However, in case, one is interested in the behaviour of the element under the axial load due to each gravity + earthquake combinations (e.g. D+0.3L+EX+0.3EY), it is still possible, but requires additional coding that is not included in this version. In the case of the beams, a zero axial load can be assigned manually for each element in the "input" tab.

2.5. Input

The main input parameters require for the CUMBIA code to analyse each RC element are defined in the "Input" tab. Most of the parameters are automatic and does not require manual adjustments. The parameters that need to be manually defined are highlighted in yellow.

3. CUMBIA_PRACTICE

Two codes have been provided that are based on the original CUMBIARECT and CUMBIACIR and modified to read the input data from the excel file discussed in Section 2. There are some manual modifications that are required for each project. The name of the input excel file is defined in Line 31. This should be modified based on the specific input file that should be analysed. This version of CUMBIA does not provide any of the figures from the original CUMBIA output. However, if one wishes to have those figures, they should either alter the code to provide the figures for each element or use the original CUMBIA for the specific elements they are interested at. Also, this version of CUMBIA does not provide moment-interaction calculations. If the moment-interaction curve is required, the code should be altered, or the original CUMBIA should be used for the element of interest.

3.1. Shear strength information

For rectangular beams and columns, some additional parameters were added for shear strength calculations. These are defined in Lines 132 – 134. The default values are based on the original parameters suggested by Priestley, Calvi and Kowalsky (2007). However, if one wishes to use other values, they can modify them. For example, Section C5 of the New Zealand Seismic Assessment Guidelines (NZSEE 2017) recommends a crack angle of 45 degrees for beams and columns as well as a 0.85 reduction factor for the total shear strength.

3.2. Other differences with the original CUMBIA

There are two minor differences between this version of CUMBIA and the original one. Here, the elastic modulus of concrete is defined based on Equation (2) as suggested in Section C5 of the NZ seismic assessment guidelines (NZSEE 2017).

$$E_c = 4700\sqrt{f_c'} \tag{2}$$

The other difference is that the ultimate strain of concrete is defined based on Equation (3) proposed by fib (2003) which is a revised version of the equation originally proposed by Paulay and Priestley (1992).

$$\varepsilon_{cu} = \left(0.004 + \frac{0.6\rho_s f_{yh}\varepsilon_{sm}}{f_{cc}'}\right) \geq \varepsilon_{spall} \tag{3}$$

In this equation, ε_{sm} should not be larger than 0.06 as recommended by Kowalsky (2000).

3.3. OUTPUT

The parameters to be tabulated in the output excel file are defined in the OUTPUT section introduced in Lines 1033 and 1051 for the CUMBIACIR and CUMBIARECT versions, respectively. Eleven output parameters defined below are available in the current CUMBIACIR_practice and CUMBIARECT_practice codes.

1. min(V): is the minimum shear strength of the element considering the reduction of V_c due to ductility.
2. max(V): is the maximum shear strength of the element.
3. failforce: is the shear capacity of the element at the intersection with the capacity curve. In the control parameters section (Line 135 or 143 of the two codes), a large value is defined as default for this parameter. If the output still shows the large default value, it means shear failure is not occurring in the element.
4. faildispl: is the displacement capacity of the element at shear failure (or shear-flexure). Same as failforce, in the control parameters section (Line 135 or 143 of the two codes), a large value is defined as default for this parameter. If the output still shows the large default value, it means that shear failure is not occurring in the element.
5. fym: is the yield moment capacity of the section defined based on Priestley, Calvi and Kowalsky (2007) which is the moment capacity of the section at the concrete compressive strain of $1.8f_{pc}/E_c$ or the yield steel strain, whichever occurs first.
6. Mn: is the nominal moment capacity of the section defined based on Priestley, Calvi and Kowalsky (2007) which is the moment capacity of the section at the concrete compressive strain of 0.004 or steel strain of 0.015, whichever occurs first.
7. eqcurv: is the yield curvature of the section.
8. dy: is the yield displacement of the element.
9. interp1(coverstrain,displ,0.004): is the displacement capacity of the element at concrete compressive strain of 0.004. This is defined as an example of how the displacement at different strain limit can be extracted for each element.
10. max(displbilin): is the maximum displacement capacity of the element from the bilinear curve. It should be noted that this parameter only covers the concrete crushing failure and does not consider other failure modes such as bar buckling or shear failure.
11. fy: is the yield stress of the longitudinal reinforcement. This parameter can be useful for assessing and designing RC elements that their behaviour is controlled by

insufficient lap splice or the longitudinal bars development length. For example, if fy is smaller than the original yield stress of the steel, yield moment capacity can be used as the maximum moment capacity of the section.

4. CUMBIA_PRACTICE_EXE

The executive code for analysing the input excel file is the “CUMBIA_practice_exe” code. It requires a few manual adjustments for each input file that are discussed below.

The input file name should be defined in Line 4.

In Line 6, the number of parameters (n_parameters) should be defined based on the number of elements of the input file that need be analysed.

The number of output parameters should be defined in Line 8 (e.g. 11 in the default version of the code).

The output excel file name should be defined in Line 20 for each input file.

5. REFERENCES

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