Columns with Low Reinforcement – Architectural Columns

For column design, the quantity of reinforcement, both vertical and spiral, and the design strength (resistance) of the column is based on the gross area of the column section. Columns are generally designed with reinforcement ratio between 1% to 8% of the gross section area. Oversized columns, widely referred to as "Architectural Columns", are often needed for functional purposes resulting in reinforcement ratios below 1%. In this article we examine how building standards treat this condition with a detailed review of the method of solution implemented in the engineering software program spColumn.

1. Relevant provisions from ACI 318

In some cases, the gross area of a column section is larger than necessary to resist the factored load. In those cases, the minimum reinforcement percentage may be calculated on the basis of the required area rather than the provided area, but the area of reinforcement cannot be less than 0.5% of the actual cross-sectional area.

ACI 318-19 (R10.3.1.2)

For columns with cross sections larger than required by considerations of loading, it shall be permitted to base gross area considered, required reinforcement, and design strength on a reduced effective area, not less than one-half the total area. This provision shall not apply to columns in special moment frames or columns not part of the seismic-force-resisting system required to be designed in accordance with Chapter 18. ***ACI 318-19 (10.3.1.2)***

If a reduced effective area is considered according to Chapter 10 provisions, structural analysis and design of other parts of the structure that interact with the column shall be based on the actual cross section. ***ACI 318-19 (10.3.1.5)***

For nonprestressed columns and for prestressed columns with average $f_{pe} < 225$ psi, area of longitudinal reinforcement shall be at least $0.01A_g$ but shall not exceed $0.08A_g$. ***ACI 318-19 (10.6.1.1)***

The basis of the code provisions in Chapter 10 is that it is satisfactory to design a column of sufficient size to carry the factored load and then simply add concrete around the designed section without increasing the reinforcement to meet the minimum percentages required by the Code. The additional concrete should not be considered as carrying load; however, the effects of the additional concrete on member stiffness should be included in the structural analysis. The effects of the additional concrete also should be considered in design of the other parts of the structure that interact with the oversize member as indicated earlier in the Code provisions.

2. Relevant provisions from CSA A23.3

The area of longitudinal bars for columns shall be not less than 0.01 times the gross area, A_g, of the section, except as permitted by Clause 10.10.5. ***CSA A23.3-19 (10.9.1)***

Columns with ρ_t, smaller than 0.01 but larger than 0.005 may be used, provided that the factored axial and flexural resistances, including $P_{r,max}$, are multiplied by the ratio $0.5\ (1 + \rho_t / 0.01)$. ***CSA A23.3-19 (10.10.5)***

3. Method of solution in spColumn

Two options are provided in spColumn for where the engineer can design a new column by selecting the shape and reinforcement (*Run Option: Design*), or investigate an existing section with known bar arrangement (*Run Option: Investigation)*

3.1. Column Design Option

In the Design run option, the reinforcement ratio cannot be less than 1.0% if Structural column type is selected in design criteria and 0.5% if Architectural column type is selected. For Architectural type, the capacity of the designed column is reduced as described above. Additionally, User Defined column type is provided in the design criteria, which allows designs with reinforcement ratios not less than 0.1%. No reduction in capacity is applied for User Defined column type. The following figures shows the dialog windows for column design criteria.

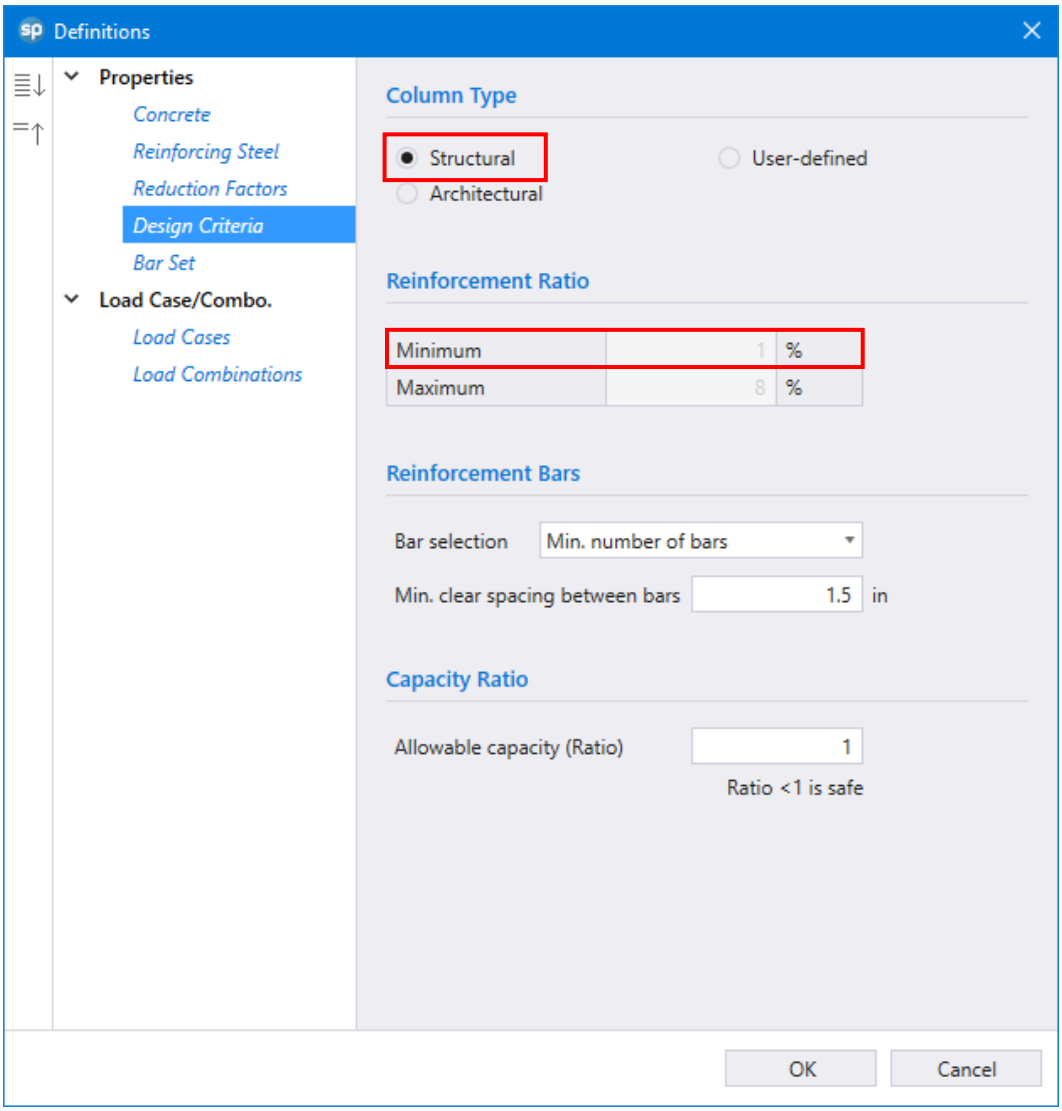

Figure 1 – Selection of Column Type (Structural) in design mode (Design Criteria)

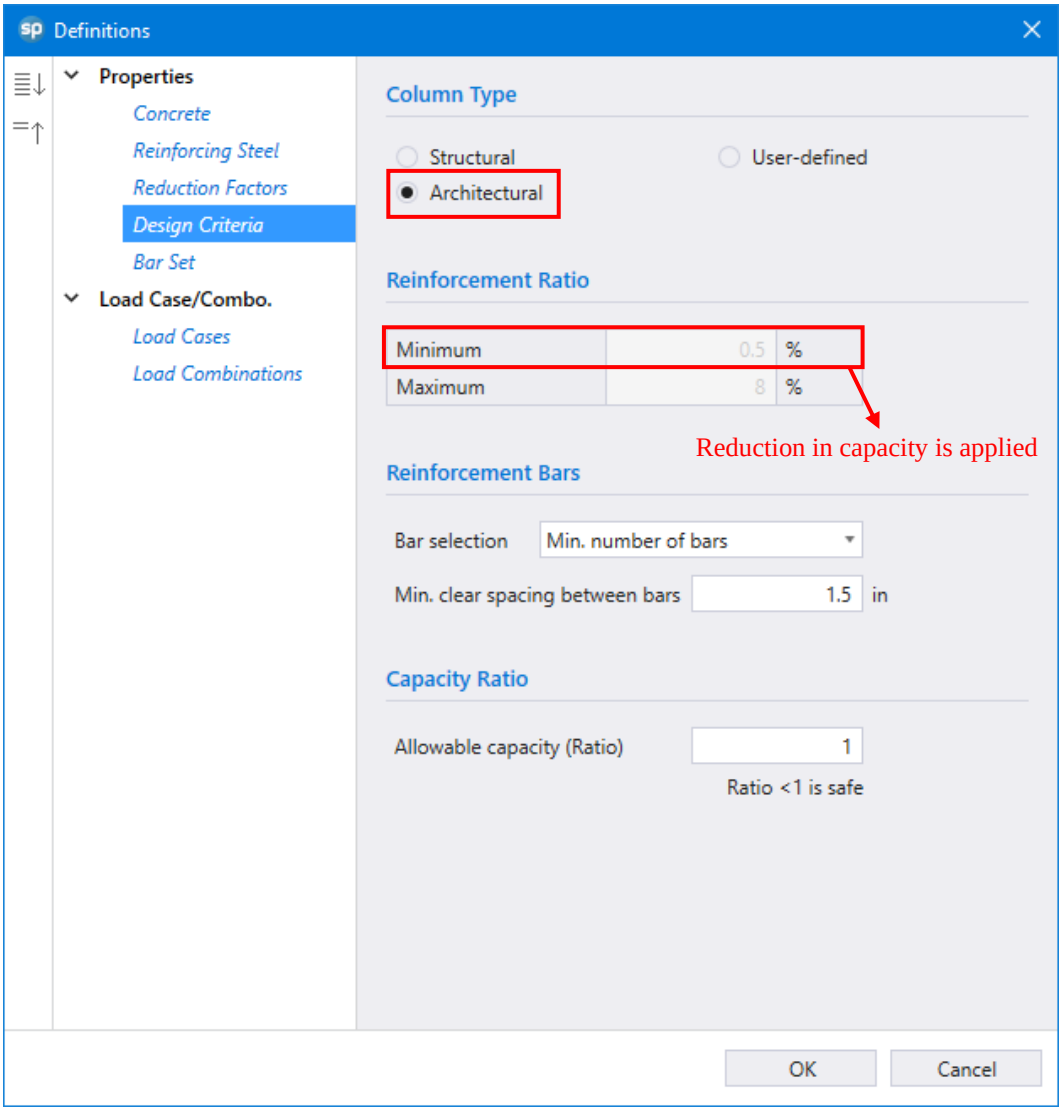

Figure 2 – Selection of Column Type (Architectural) in design mode (Design Criteria)

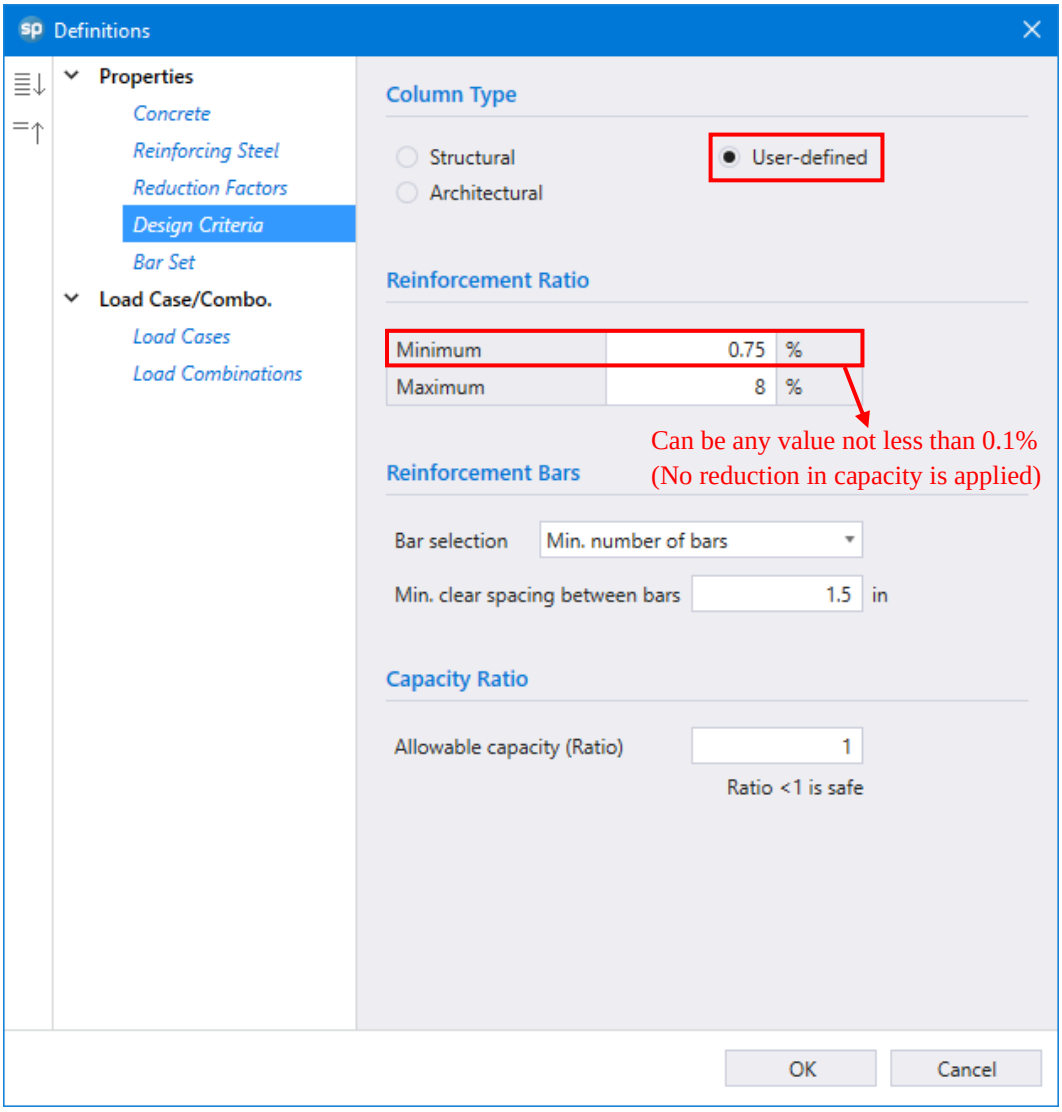

Figure 3 – Selection of Column Type (User-defined) in design mode (Design Criteria)

3.2. Column Investigation Option

In the investigation run option the program will calculate the capacity for any provided area of reinforcement. However, if the reinforcement area falls below the code-specified minimum of 0.01 times the gross area, A_g, then spColumn will issue a user note requesting a decision to determine the column treatment as Architectural or user-defined as shown below.

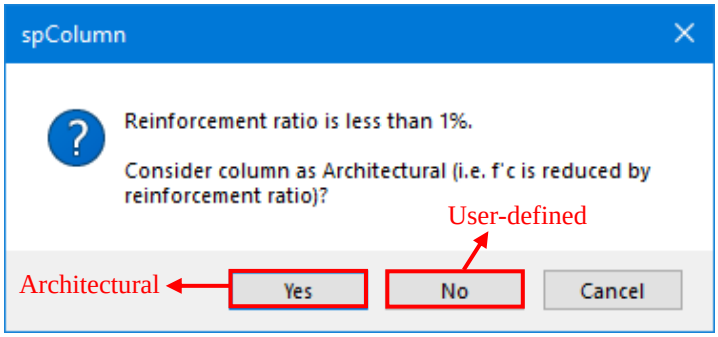

Figure 4 – spColumn user note when reinforcement ratio is less than 1% in investigation mode

By default Architectural option is selected for which the capacity of the section is reduced. For the ACI codes, the reduction results from multiplying the maximum concrete stress, f_c', by the ratio of reinforcement area to $0.01A_g$. This produces the same effect as reducing the effective concrete area to achieve ratio of reinforcement 1.0%. For the CSA standards, the factored axial and flexural resistances are multiplied by ratio $0.5\ (1+ \rho_t / 0.01)$.

For user-defined option, the section is treated "as is" without any reductions in capacity. This option is provided for informational purposes only, since the capacity of compression members with reinforcement area less than $0.01A_g$ has to be reduced and areas below $0.005A_g$ are not allowed by all codes supported by spColumn.

A 24 in. square column is used to illustrate spColumn interaction diagrams superimposed for both column design criteria showing the impact of capacity reduction for the Architectural (oversized) column type. The structural column interaction (with ratio under 1%) is shown by spColumn for information only since it is not sanctioned by code provisions for column section. However, the diagram may be informative for non-column structural members where lower reinforcement ratios are permissible such as walls where the permissible vertical reinforcement ratio can be as low as 0.12% (ACI 318-19 Table 11.6.1) or in oversized beams and diaphragm slabs where reinforcement ratio can be as low as 0.18% (ACI 318-19 24.4.3.2).

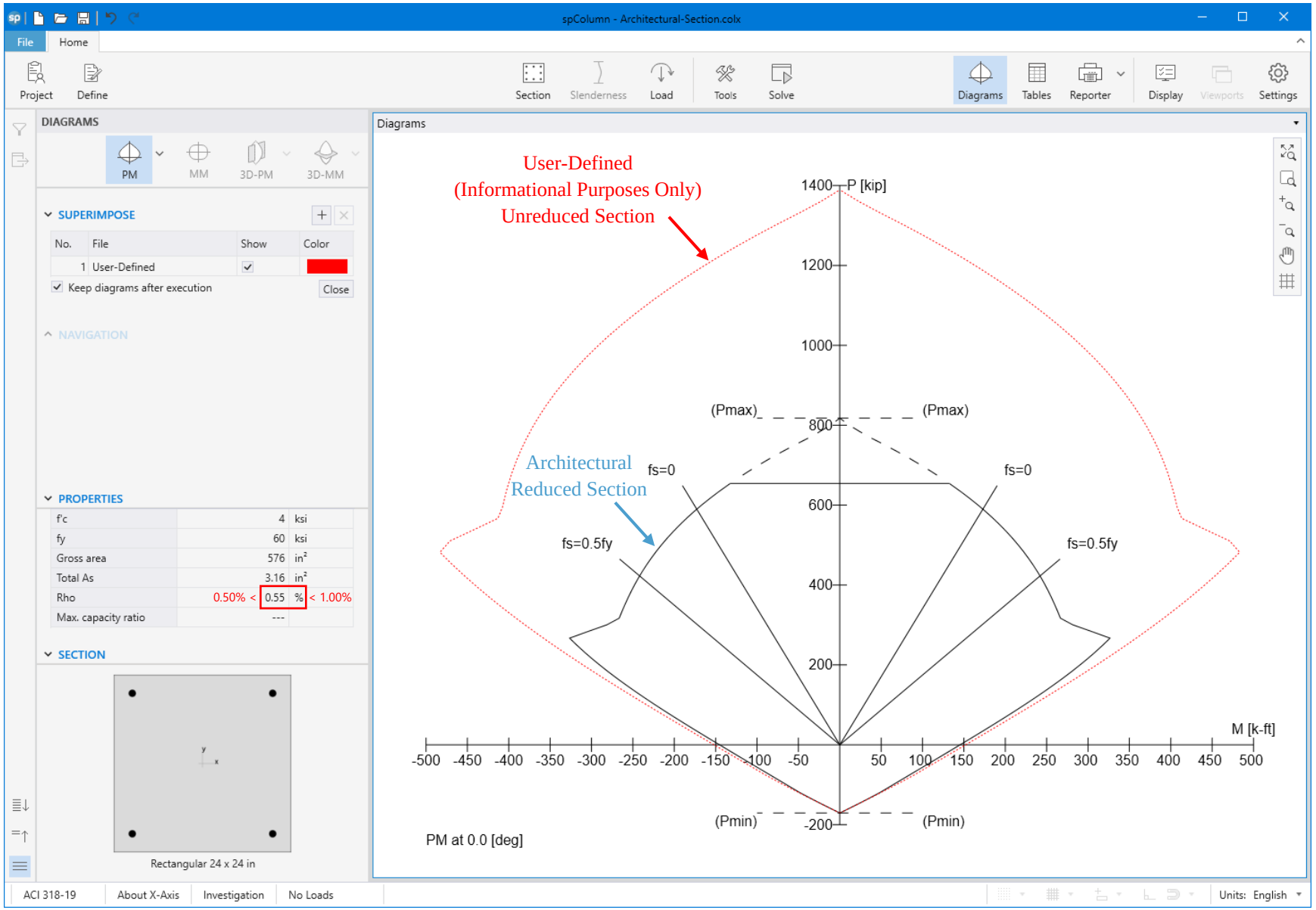

Figure 5 – Superimposed Architectural and User-Defined Factored Column Interaction Diagrams

Conclusions & Recommendations

Engineers are encouraged to take a closer look at the reinforcement ratio of structural members subjected to combined axial and flexure loads to determine the appropriate calculations to arrive to the section capacity. Similarly, it is suggested to evaluate the economy of steel quantity provided in massive and oversized members to deploy the architectural column type in the design criteria to achieve an economic and safe design.

Engineering judgment is required to decide whether to reduce the section capacity based on code provisions when using the engineering software spColumn. This document recommends the following when using spColumn when investigating the adequacy of structural members with low reinforcement ratios subjected to axial and flexural loads:

1. Considering the column as architectural when the reinforcement ratio is between 0.5% and 1%. In this case, the column axial and flexural capacities will be reduced based on the selected code provisions.
2. For columns, avoid using reinforcement ratios less than 0.5%.
3. Consider the member as user-defined when the reinforcement ratio is less than 1% for other structural members such as walls, beams, and diaphragm slabs.