Reduced Beam Section Design Using Matlab

Kaan Bilgin
Civil Engineering Department
MEF University
Istanbul, Turkey
bilgink@mef.edu.tr

Abstract: This paper describes the Reduced Beam Section (RBS) connection design procedure and MATLAB solver for design, with detailed explaining about the solver's working system within the boundary conditions for user inputted section values. Imperial unit system version of the MATLAB code tested with W24X55 beam and W14X257, W14X342 columns, and the SI unit system version tested for HEB450 beam, HEM400 and HEM500 columns. All limitation and section properties are defined in the report. Respective radius cut parameters with finalized Plastic Moment Capacities are calculated with MATLAB solver and reported.

Keywords: Reduced Beam Section, Seismic Design, Special Moment Frame, Plastic Hinge, Plastic Moment Capacity, MATLAB

I. INTRODUCTION

In seismic active areas, buildings need to dissipate notable energy during earthquake to prevent major damages and life loss. This can be achieved with highly ductile structural elements. Reduced Beam Section Connection design is an essential design strategy for earthquake resistant steel structures with steel special moment frame. Reduce the beam section to improve the ductility of the beam, so that the stress concentration is transferred to an area away from the connection. This paper will be about the development of a MATLAB function to operate the RBS connection design process, which is an iterative process within its boundary conditions for each connection in whole structure, and aims to provide the optimal steel section connection design parameters to the user to minimize the time consume of the iterative process.

A. Abbreviations and Acronyms

- b_f Beam Flange Width, *inch (mm)*
- d_b Beam Depth, *inch (mm)*
- d_c Column Depth, *inch (mm)*
- M_f Probable Maximum Moment at the Column Face, *kip-feet (kNm)*
- M_{pr} Maximum Moment at the Center of the RBS, *kip-feet (kNm)*
- R_y Tensile Strength Ratio, *unitless*
- t_{bf} Beam Flange Thickness, *inch (mm)*
- t_{bw} Beam Web Thickness, *inch (mm)*
- t_{cf} Column Flange Thickness, *inch (mm)*
- t_{cw} Column Web Thickness, *inch (mm)*
- V_{rbs} Shear Force at the Center of RBS, *kips (kN)*
- W_D Dead Load, *kip/ft (kN/m)*
- W_L Live Load, *kip/ft (kN/m)*
- Z_{rbs} Plastic Section Modulus of RBS, *inch^3 (mm^3)*
- Z_x Plastic Section Modulus of Section, *inch^3 (mm^3)*
- F_u Yield Strength of Steel Section, *kip/ft^2 (N/mm^2)*
- F_y Ultimate Strength of Steel Section, *kip/ft^2 (N/mm^2)*

B. Units

- Respective units are defined and reported in Imperial Unit System and SI Unit System equivalents are highlighted in parenthesis. Respective results are reported in for both Imperial Unit System and SI Unit System.

II. REDUCED BEAM SECTION CONNECTION

A. General

In a connection with reduced beam section (RBS), parts of the flanges of the beams are selectively radius cut in the area adjacent to the beam connection to columns. Yielding and formation of hinges aim to happen primarily on reduced part of the beam.

B. Systems

RBS connections are prequalified for use in special intermediate moment frame systems under provisions.

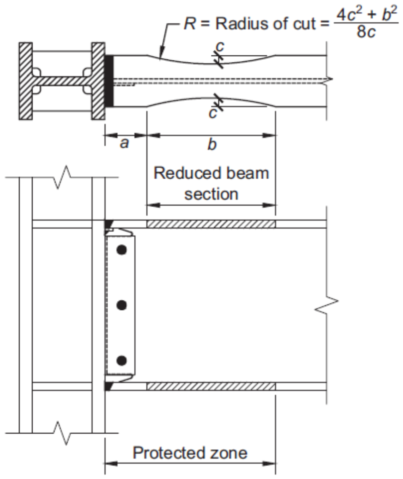

Fig 1. RBS Connection [(1)]

1. *Limitations on Beam Dimensions*

- Beam must not exceed W36 (1040 mm)
- Beam must not exceed weight 302 lb./ft (447 kg/m)
- Beam flange thickness must not exceed 1-3/4 inch (44 mm)
- Clear span to ratio over depth must be equal or greater than 7 (for both system).

2. *Limitations on Column Dimensions*

- Columns' depth must not exceed W36 (1040 mm)
- No restraints on column weight, flange thickness and web thickness.

C. Design Procedures

1. Trial values for the beam section selected

$$0.50b_{bf} \le a \le 0.75b_{bf}$$
$$0.65b_{bf} \le b \le 0.85b_{bf}$$
$$0.10b_{bf} \le c \le 0.25b_{bf}$$

Eq 1. a, b, c trial values [(1)]

a Column Flange to RBS Cut Distance, *inch (mm)*
b Length of RBS Cut, *inch (mm)*
c Depth of Cut at Center of RBS, *inch (mm)*

2. Plastic section modulus calculation at the center

$$Z_{RBS} = Z_x - 2ct_{bf}(d - t_{bf})$$

Eq 2. RBS Plastic Section Modulus after cutting [(1)]

3. Maximum probable moment calculation at the center

$$M_{pr} = C_{pr}R_yF_yZ_{RBS}$$

Eq 3. Maximum Probable Moment [(1)]

4. Shear force acting on the reduced beam section at each end calculation

5. Maximum probable moment at the face of the column calculation

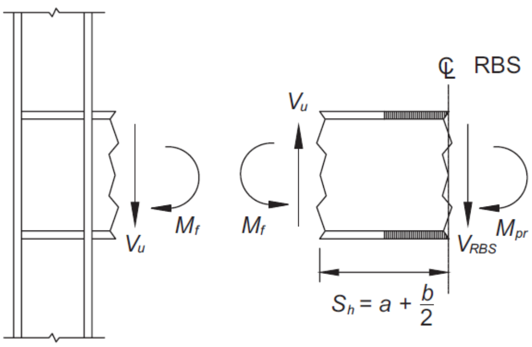

Fig 2. Free Body Diagram [(1)]

$$M_f = M_{pr} + V_{RBS}S_h$$

Eq 4. Probable Maximum Moment at the Face of Column [(1)]

S_h Face of Column to Plastic Hinge Distance, *inch*

6. Plastic Moment of the beam based on the expected yield stress

$$M_{pe} = R_yF_yZ_x$$

Eq 5. Plastic Moment of the Beam for Expected Yield Stress [(1)]

7. Final Flexural Strength of the beam checking

$$M_f = \O_d M_{pe}$$

$\O_d$ LRFD Design coefficient, *unitless*

Eq 6. Flexural Strength of the Beam at the Face of the Column [(1)]

D. Test Sections and Results with MATLAB

Table 1. Imp. Test, Section Properties

	t_f (*inch*)	t_w (*inch*)	d (*inch*)	b_f (*inch*)	Z_x (*inch³*)	Weight (*lb./ft*)
W24X55	0,505	0,395	23,6	7,01	134	55
W14X257	1,89	1,18	16,4	-	-	-
W14X342	2,47	1,54	17,5	-	-	-

```
No limitation on column weight and column flange thickness. Thus, the RBS can be used.

Mf is smaller than MFinal thus the process completed.


  a: 4.380 inch     b: 17.700 inch    c: 1.230 inch    Zrbs: 105.309 inch^3    Cpr: 1.150

  Mpr: 555.067 k-ft    Sh: 13.230 inch    Lh: 26.383 ft    Vrbs: 51.325 kip    Mf: 611.653 k-ft

  Factored_Mpe: 614.167 k-ft>>
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Fig 3. MATLAB Command Window of the Results IMP System RBS Calculation

Table 2. SI Test, Section Properties

	t_f (mm)	d (mm)	b_f (mm)	Z_x (cm^3)	Weight (kg/m)
HE450B	26	344	300	3982	171
HE400M	40	298	-	-	-
HE500M	40	390	-	-	-

```
No limitation on column weight and column flange thickness. Thus, the RBS can be used.
Mf is smaller than MFinal thus the process completed,


 a: 188mm   b: 258mm  c: 58mm Zrbs: 3022912mm^3 Cpr: 1.19

 Mpr: 1404.898kNm Sh: 0.317m Lh: 6.522m Vrbs: 454.461kN

 Mf: 1548.962kNm Mfinal: 1554.971kNm>>
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Fig 4. MATLAB Command Window of the Results SI System RBS Calculation

E. References

[1] AISC 358-16, *Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications*