THE STUDY OF ENERGY ACCEPTANCE FOR RIGID CONNECTIONS WITH NUMERICAL METHODS

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ABSTRACT:
Generally we can use the members of extra internal strength with rigid connections. In this case, whenever a point is over loaded, another distribution happens in the length of the member for extra stresses. With applying to this connections , negative moment that is created in the fulcrum , reduces the affirmative moment which is placed in the middle of the mouth and because of this the section surface that is needed , decreases and so it economics the amount of steel. Rigid connection is the best type of connection among all types of beam to column connections that the only problem with it is the weakness and difficulty in executing it, however, about this connection there were not a lot studies or at most it is limited in appointing the stiffness or shear and moment in the region of connection. Therefore in this paper we have tried to make use of numerical methods (e.g. finite elements) in modeling this connection that is a minute and efficient method and recently according to the increase in speed and efficiency of high speed computers has been in vague.
And finally, one of the important features of this connection is, energy ductility will be considered with this method and by using available plans.

KEYWORDS: rigid connections, ductility, energy acceptance

1. INTRODUCTION

Generally, extra inner resistance of members, which appears only in cases of continuity, can be prevented by using rigid connection. In such case, whenever the load exceeds allowed limitation in a point, re-distribution occurs along the member for the extra stresses. Applying this connection, negative anchor created in support as well as positive anchor reduce outlet center. The module of required section too will be reduced, and consequently steel consumption will be saved. Rigid connection is the best type among all types of beam-to-column connections, the unique problem of which is difficulty to execute. However, not so many examinations are conducted about this connection, or the most they are limited to determination of hardness, cutting, and anchor at connection point. In this research, it is tried to use digital method (limited elements), which is a precise and effective method, for modeling this connection. Important specification of this connection, which is its higher energy-acceptability in comparison with other common connections, is reviewed here.

2. GENERAL MODEL OF CONNECTIONS

Connection can be modeled using a spring and various hardness degrees. According to what specified in figure 1, through increasing the spring hardness from zero to infinite, the connection can be modeled from fully joint to fully rigid.
As seen, a beam is considered between two columns, the connection of which is fully rigid; and this connection can be turned to fully gagged connection by increasing the rigidity.

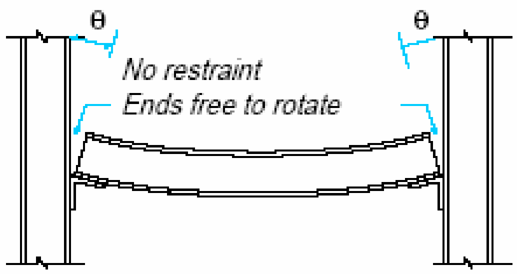


Figure 1. A spring with rotating hardness for connection modeling

3. TYPES OF CONNECTIONS

AISC regulation recommends four types for beam-column connections in steel structures, as shown in table 1.

Table 1. Types of beam-column connections in steel structures according AISC

Type of Connection	Name of Connection	restraint
1	Simple frame	<20%
2	Semi-Rigid frame	>90%
3	Rigid frame	20%< <90%
4	Plastic design	

4. DEFINITION OF BEAM-COLUMN RIGID CONNECTIONS

While applying beam-column rigid connection, the designer intention is that this connection is unable to shift moment, and no comparative rotation is created among the members entered into connection. Actually, this is the connection type 2 in AISC. Applying this connection, extra inner resistance of the members, which appears just at continuity condition, can be used. In such case, whenever the load exceeds allowed limit in one point, re-distribution occurs along the member for extra stresses. Negative moment created in support reduces positive moment of center span, and thus the module of necessary section is lowered, consequently steel consumption is saved. The issue of rigid connection is a matter which is neglected by experts of the field, and is attended lesser in comparison with other issues. The reason may be sought in difficulty of execution of such connections.

Since the effect of bending moment is carried in the form of a couple of forces in tensile and pressure wings of the beam with almost equal heights, main role of a rigid connection is providing facilities for transfer of these axial forces.

Furthermore, as major part of this cutting strength is carried by the beam web, complete continuity of connection requires that cutting strength is transferred directly from web. In a beam-column connection, the beams may be connected from two sides to both wings, or just to one wing of the column. Also it is possible that, the beams are connected from one or two sides to the column web as rigid.

If in a rigid frame system, beams are connected only from two sides to two wings or webs (of course not together), it is called two-way or plate rigid frame system. The rigid frame system which includes a connection where beams are connected from four sides to two wings and webs of the beams (although it may be to only one side of the web is called spatial or four-way rigid frame. Rigid connection has four main functions:

- shift the ending moment of the beam-column
- shift the ending shear of the beam-column

Properly executed rigid connection is the best of all types of beam-column connections, the only problem of which is its weakness and difficulty in execution. However, there are not many reviews about this type of connection, or at most they are limited to determination of hardness or cutting and anchor at connection point. Generally, proper rigid connection should have sufficient strength, ductility, and energy acceptance capability.

5. ENERGY ACCEPTANCE AND DUCTILITY

As mentioned above, suitable rigid connection should have sufficient strength, ductility, and energy acceptance capability. Sufficient ductility means proper load-bearing capacity and deformation. Level of ductility of a structure is determined by a co-efficient called ductility co-efficient. The amount of this co-efficient indicates capacity of energy acceptance of the parts or whole structure, and is better to obtain through testing. Determining this co-efficient for structures higher than one floor is a complicated task, for calculation of which comparative dislocation of the floor is used as deformation criterion. On the whole, steel structures with bending frame have higher ductility. The level of absorbed energy by members is one of the important factors in examining the behavior of a structure in earthquakes. Ductility can generally be assigned to the behavior of materials after their elastic stage.

For a structure to be sufficiently ductile, its constituting materials should be such that the variety of length before missing link is great enough, and the ratio of ultimate stress to yield stress is close to one. In this matter, we can refer to stress-strain of steel curve which is under pressure of repetitive back and forth loads. Once the load quantity exceeds zero, deformation of member will increase in elastic form until it reaches yield stage. Then deformation increases as non-elastic until the load is reduced. When the load is reduced down to zero again, residue deformation remains in the member. If similar loading is entered in opposite direction, the curve will be repeated in another half-loop form, and finally it will return to its starting point. A loading cycle in two opposite and negative directions forms a full loop, and the level of absorbed energy by member is attained through calculation of inner surface of the loop.

As higher the level of energy absorption in a member, more suitable the behavior of member will be when earth-quake. For steel, it can be easily obtained from the results of steel direct tension test on small samples. Also, it is clearly recognizable from the relationship between bending anchor and curve in hysteresis loops. Tests and examinations on rigid connection indicate high energy-acceptance of connections, and if the connections are of welding type, they have mortality 3 times higher than joint connections.

6. SELECTED MODEL

Generally, mathematical model of structural systems is classified in two groups:

- Macro Modeling: In this method, the behavior of a rather large area of structure, including beam, column, and wall, is modeled.
- Micro Modeling: This modeling is based upon mechanical properties of materials and the limited elements method, which is (more) suitable for continuous systems.

There are various methods for examining energy acceptance of rigid connection. In this research, numerical method is used. For this reason, we have tried to examine this connection using numerical method by selecting a suitable model. Evolution of finite elements method for analyzing structural systems showed that it has major affect on modeling methods for types of materials including steel. Finally, considering all above matters, in this project, a common type of console beam-column rigid connection (including upper and lower wings connection plates, and web connection plates) was modeled and reviewed (figure 2) by finite elements method in the form of connection of one console to column with dynamic loading in a time history. Finally, its ductility and energy acceptance were reviewed.

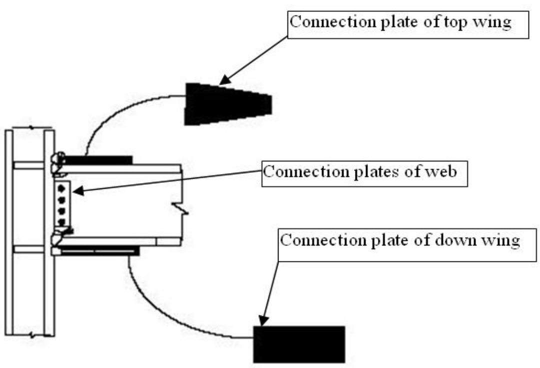


Figure 2. Main preliminary model of rigid connection

The connection was considered with the following properties:

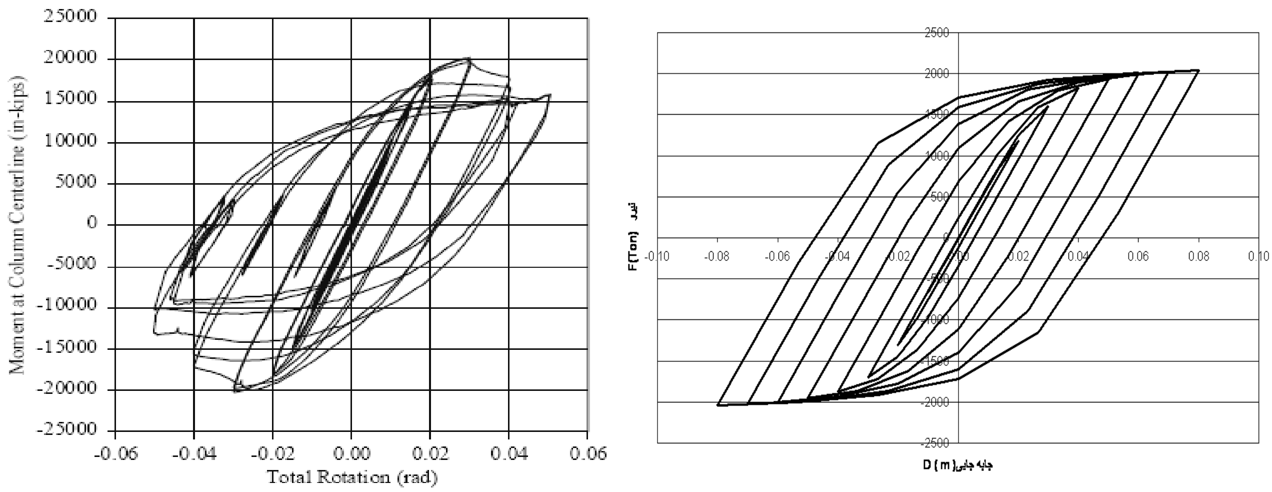
- Upper wing connection plate : at 1×8×20 cm and 8 mm welding dimension
- Lower wing connection plate : at 1×8×20 cm and 8 mm welding dimension
- Web connection plates : two plates of 1×15×10 cm, and 8mm welding dimension

7. ANALYSIS STEPS

The steps of model analysis are as follows:

- Step 1: Naming and selection of units
- Step 2: Definition of elements and introduction of geometric
- Step 3: Determination of the materials properties
- Step 4: Drawing the geometric model
- Step 5: Mesh generation
- Step 6: Boundary conditions definition
- Step 7: Loading, and their time history
- Step 8: Analyzing and solving the problem

As mentioned above, analyzes were done; errors were corrected, and rotation-moment curve loops were drawn. The extent of rotation was obtained from dividing dislocation of two selected points of the beam and column, and moment quantity was obtained from multiplying strength by relevant arm in connection source. According to hysteresis curves (figure 3), in fully rigid connection, rotation is changing between -0.05 to +0.05.



(a) (b)

Figure 3: hysteresis curves
a) rotation-moment in connection point for sample rigid connection under earthquake load;
b) force-displacement under static load

Rigid connection has higher ductility and energy acceptance when compared with other types of connections. This ductility is clearly recognizable from relationship of bending anchor and curve in drawn hysteresis loops. It is seen that hysteresis loops are in conical shape, having vast surrounded area, which indicates its high energy absorption.

8. CONCLUSIONS

Considering above mentioned, the results of concluded research are as follows:

- A rigid connection with precise execution of stable residue loops is in conical shape with vast surrounded area, and higher strength than yield strength, which indicates its high energy absorption and ductility compared with other connection types.
- For the connections welded with wing patches, tracks starts from the beginning of plate patch and the end of corner weld, accordingly they have lower ductility.
- In this type of connection, strength reduction is rarely observed; even if diametric buckling occurs due to affect of cutting power in panel.
- Connection welds are critical, and sometimes their stress becomes several times higher than allowed level. The best section for prevention from concentration of stresses on welds is triangle shape. This weld section form causes reduction of stress concentrations at the place of welds cutting.
- When designing, side deformations of column, which causes tension and pressure in the weld, should be attended.
- Rotating moment resulted from extra-axis main beams causes that column pate is turned under the side load, and the said rotating anchor is collected with bending moment resulted from gravity loads. In this state, main beam rotating side buckling is increased, which should be examined carefully.
- Possibility of crushing in edges of main beam between wings and webs should be considered.

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