Interdependence between Structural Engineering and Construction Management
Edited by Ozevin, D., Ataei, H., Modares, M., Gurgun, A., Yazdani, S., and Singh, A.

ISBN: 978-0-9960437-6-2

LOAD BEARING STRUCTURAL ASSEMBLY

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This article is based on an invention focused on absorbing and redirecting forces two dimensionally or three dimensionally in any mechanism that relies on force resolving members, so more benefits of the mechanism can be achieved. This Assembly is focused on new ideas for framing and connections to resolve forces so the rigidity between members can be minimized and the Assembly can sustain performance under longer durations and more unique loadings, i.e., seismic loading on structure. The Assembly uses several techniques and fundamentals for efficient force dissipation with, or without deflection while creating a controlled rotation when loaded. The allowable arrangement of the Assembly within itself (web members within outer and inner rings and arcs), and as an assortment of assemblies, can be limitless. This arrangement, configuration of web members, numbering, width and flexibility, can be arranged for a predictable and controlled deflection or rotation in any direction, due to loading from any direction and type, thus creating a load bearing and load dissipating Assembly with greater efficiency, and advance the life of interacting parts under loadings, i.e., seismic loading of structures. This Assembly, in particular the web members, can be an arrangement and properties of arcs to offer a desired response, as well as create a rotation when loaded.

Keywords: Absorbing, Redirecting, Extending, Force manipulation, Controlling.

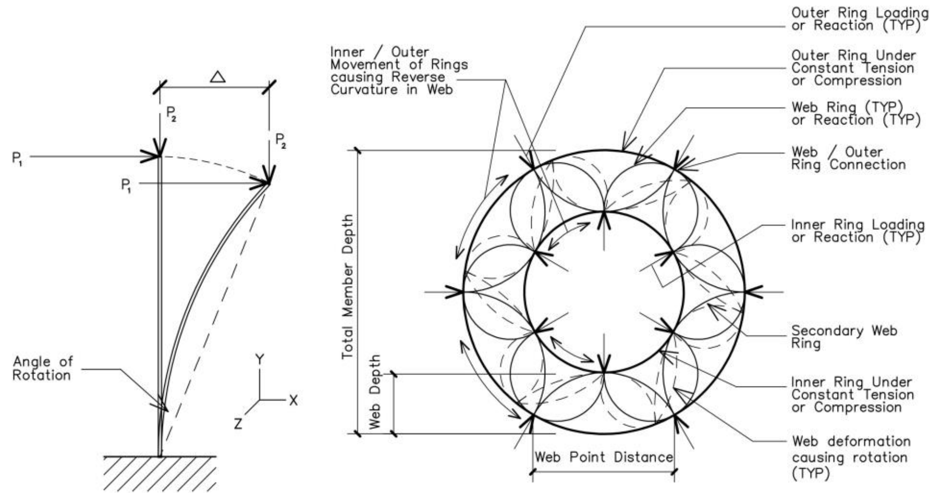
1 INTRODUCTION

The Assembly is focused on new ideas for framing and connections to resolve forces so the rigidity between members can be minimized and the Assembly can sustain performance under a longer duration and more unique loadings. The Assembly is used to change linear (horizontal or vertical) acceleration and loading into a rotation about a point thus controlling the eccentricity on the critical load bearing members of the structure, i.e., columns (United States Patent and Trademark Office 2013, 2014).

2 DESCRIPTION OF ASSEMBLY

As shown in Figure 1b, the Assembly includes an outer loop (arc) member; an inner loop (arc) member spaced apart from and sized smaller than the outer loop (arc) member; a web assembly coupled to and extending between the outer loop (arc) member and the inner loop (arc) member, the web assembly comprising a plurality of arcuately formed web members.

The arcuately formed web members and end connections allow the members to go through increased curvature during loading while creating a controlled rotation in excited events, similar to the loads generated from seismic forces on structures. The properties of each outer and inner ring (arc), as well as web members and their end connections, i.e., fixed, pinned, can be selected for a controlled performance – that of controlled directional movement or rotation, or lack thereof.



a. Similar Equivalent Loading. b. System Loading.

Figure 1. Load bearing structural assembly, i.e., 'ForceGenie' component section / elevation schematic.

The Assembly is literally a flat or 3-dimensional spring, which can be designed for a confined space and provide an array of outcomes or interact with an array of forces. The circumferential rings have minimal deformations because of the bracing effect of the web members, and the extensions of the web members through bending causing rotation of the Assembly rings and compression / tension in the circumferential rings (arcs) (Russell 2015).

3 BENEFITS OF ASSEMBLY

The Assembly's, i.e., ForceGenie's, design is a response to structural failures during extreme events on the structural connections and created by dissipating of the energy from the events. When the inner or outer ring is loaded, it generates a rotation (spin) in relation to the other by bending of the web members (Ref. Figure 1b). This rotation about a center will have the tendency to control the eccentricity of the vertical loading and dissipate energy in movement and heat. As well, in this bending of the Assembly's web members, a web member can be placed into single curvature, or double curvature through the addition of mid rings (Figure 2) and increase the performance of the web member section along the length.

The loading of the Assembly will cause a rotation (spin) of the inner and outer rings simply because the web members are much stronger in compression than in bending, and the web members are pre-formed in a bent shape (arc). In ideal conditions, the rotation (spin) of the inner and outer rings, in a cyclical event, will put the web members into full tension and bending, and rings into tension and braced compression. In addition, the amount of rotation (spin) can be predicted by simple structural analysis and angle of rotation set by the design of the members, i.e. Moment of Inertia, the quantity of web member arcs, the spacing of the arcs around the parameter of the rings, etc. (Russell 2015).

4 FUNCTION OF THE ASSEMBLY

As depicted in Figure 1, one can see the analogy with the bending of column and a possible configuration of the members. With this, one can recognize the efficiency of the circle (arc) can be used to generate efficiency in strength, in particular in bending, but also in compression, tension, and shear of the web members. The allowable arrangement of the Assembly (Figure 1, 2 and 3) within itself (web members within outer and inner rings (arcs), and as an assortment of Assemblies, can be limitless (Refer to Figures 2 and 3 above for possible configurations). In Figure 1b is shown an Assembly with six ring (arc) groups of web members. The web members can be of any arc arrangement separating the inner and outer rings. (Additionally, the outer and inner rings can be of an assortment of arc configurations, i.e., elliptical, tear-shaped, etc. for a specific required response.)

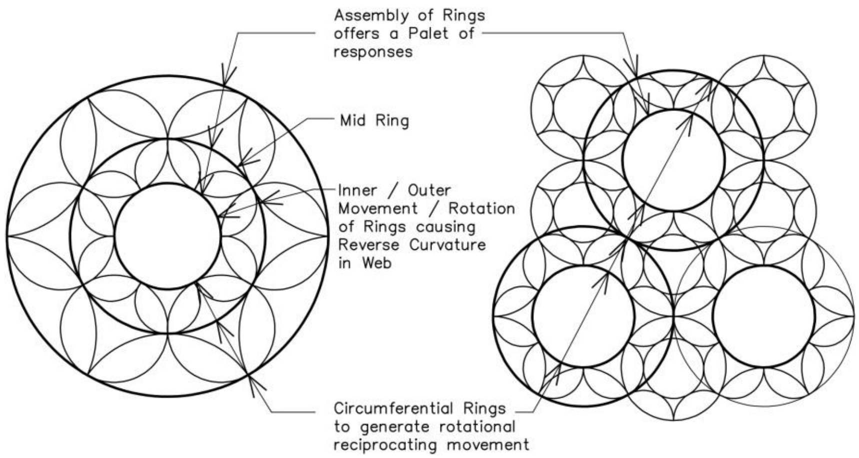


Figure 2. Circumferential rings (arcs) elevation.

Figure 3. Assortment of rings (arcs) elevation.

This arrangement, configuration of web members, web numbering, web width, web flexibility, etc. can be arranged for a predictable rotation (controlled deflection) in any direction, due to loading from any direction (Figure 1b) and type, all while keeping the members within the elastic and inelastic range and thus creating a load bearing, a load dissipating Assembly with greater efficiency in a cyclical event. This will tend to enhance the life of interacting parts under repetitive or reciprocating loadings, i.e. seismic loading on structures. The Assembly rotates due to the ease of displacing a web member (bending) rather than compressing the member length. Refer to Figure 4 for a possible connection integrating the Assembly.

The rotation of a ring in relation to the other (inner or outer) is achieved by directional displacement (rotational) from the differing moment of inertia of member directions under loadings, i.e., bending about the axis (Ref. Figure 1a for axis orientation). That is, in this case the moment of inertia about the 'Z' axis is much less than about the 'X' axis and 'Y' axis, and the kl/r is sufficient to cause bending of the member rather than failure in member compressive stress. The dimensions of the cross section in the members are set so bending is assured in one direction (i.e. about the 'Z' axis) and thus rotation of the rings occurs.

5 ENGINEERING PRINCIPLES OF THE ASSEMBLY

The Assembly makeup has the effect of isolating the excited loading, buffering the impact of seismic (or other cyclic event), and may prevent collapse. Figure 1 earlier shows directional forces on the Assembly; however, the forces on the inner and / or outer rings can be in any direction from predictable loadings and cause the rotation between the rings (arcs) unique to the Assembly.

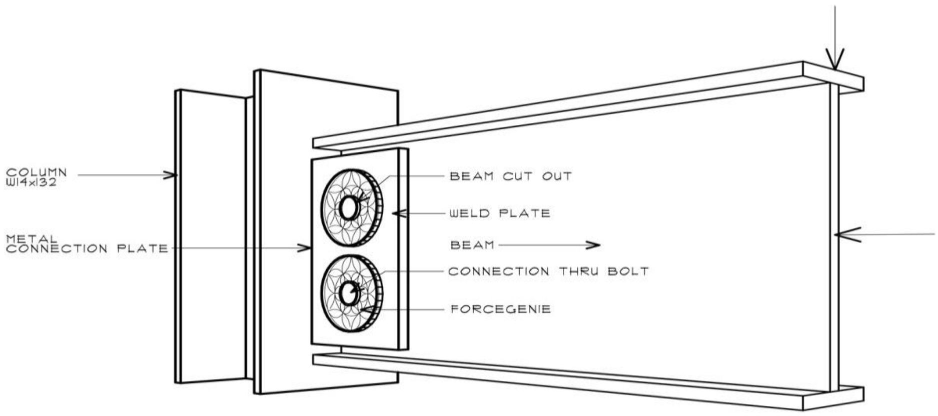


Figure 4. Assembly flange connection perspective.

$$F \leftrightarrow \tau = r\,F_{\perp} \quad (\text{N, lbf} \leftrightarrow \text{rad/sec}^2) \tag{1}$$

$$F_{net} = M\,a \leftrightarrow \tau_{net} = I\,\alpha \,(\text{N, lbf} \leftrightarrow \text{rad/sec}^2) \tag{2}$$

Eq. (1) and Eq. (2) show engineering formulas for Translation (X, Y, Z) and Rotation. One can see the F_{net} generated from the acceleration (i.e. seismic forces on structure) is converted into a rotational acceleration. This acceleration occurs to all mass, but because of the loading points of the Assembly occur around the parameter (inner or outer rings), the web members move into reverse curvature from the current position and are put into tension, and the adjoining web member into bending. This web member bending and ring rotation can be uniquely designed so that when it is loaded and the web arch ends are fixed or pinned, the inner / outer rings (arcs) move through a predictable angular deflection (rotation).

Table 1. Modified Mercalli intensity scale.

Instrumental Intensity	Acceleration (g)	Velocity (cm/s)	Perceived shaking	Potential damage
I	< 0.0017	< 0.1	Not felt	None
II–III	0.0017 – 0.014	0.1 – 1.1	Weak	None
IV	0.014 – 0.039	1.1 – 3.4	Light	None
V	0.039 – 0.092	3.4 – 8.1	Moderate	Very light
VI	0.092 – 0.18	8.1 – 16	Strong	Light
VII	0.18 – 0.34	16 – 31	Very strong	Moderate
VIII	0.34 – 0.65	31 – 60	Severe	Moderate to heavy
IX	0.65 – 1.24	60 – 116	Violent	Heavy
X+	> 1.24	> 116	Extreme	Very heavy

The Modified Mercalli Intensity Scale gives us a range of the seismic events. The Assembly can be designed accordingly by the respective ranges of acceleration and velocity along with the loading of the specific structures to determine the respective forces causing displacement or rotation. The number, properties, and arrangement of the web members are selected so to generate a designed and predictable rotation before the web members go into tension and bending (Refer to Figure 1b for deflected shape).

The Assembly reaction will have the effect of dissipating the forces, distributing the moment and shear through the members with respect to inflection points, and will tend to limit the maximum values accordingly. Or the web members can move, with angular deflection (rotation), through single curvature with the use of hinge connections on the ends of the arc to the inner and outer rings.

With respect to the assemblies shown in the figures, the loading of one ring (either inner, outer, or both) can be from any direction and have the same twisting affect because of the nature of the arc web members being set in curvature. The Assembly can be as big as the Main Force Resisting System of the structure (i.e. many feet) and / or as small as a connection component (i.e. less than an inch). The strength of the Assembly is achieved when it is loaded it causes rotation and loss of energy into the system through force dissipation, ring and mass displacement.

Potential energy can be stored in either masses or springs. In a spring the potential energy, U, is given in Eq. (3):

$$U = \int f(x) * dx = \int k * x * dx = ½ k * x^2 \quad (3)$$

(k = spring constant, x = displacement (rotation)

For a mass moved in a constant gravitation field as in the Assembly is given as Eq. (4):

$$U = \int f(x) * dx = \int m * g * dx \quad (4)$$

(m = mass of structure, g = acceleration of gravity, i.e. 9.8 m/s^2, 32.2 ft/s^2)

In the ideal sense, we want the friction forces between the Assembly and the structure to never be realized so energy is not transmitted to the structure. The energy dissipation is created by movement of the web members in, and through the elastic, and into, and through the inelastic range. There are significant energy losses with this movement when converted into heat energy. The mechanical energy is then transported to the rings, which increases the kinetic energy of the Assembly. Some of this kinetic energy is lost to heat energy from the friction between the Assembly and the structure, and some is lost to the Assembly and the web members (arcs) in the act of rotating.

6 RATIONALIZATION OF THE ASSEMBLY

The Assembly only accounts for the above grade forces as they interact with the various levels of the structure (in early development of foundation interaction with the structure). Additionally, the Assembly should be used throughout the structure so there is no induced rotation in the structural diaphragms and the energy of the event is released in the Assembly. The two-dimensional nature of the Assembly shown in Figures works nicely with the horizontal and vertical accelerations of the seismic event, and the orthogonal framing of structure will tend to protect multi-directional of the possible seismic events.

Numerous other arc web arrangements for the Assembly can be set for specific spatial allowances, specific loading requirements, and specific rotational displacements needed. The effect of the Assembly on the building is that of changing Natural Frequency of the structure. A structure, which is positioned for optimal performance in an earthquake is that of a box, which moves with a stiff earth surface. If the period of ground motion matches the natural resonance of a building, it will undergo the largest oscillations possible and suffer the greatest damage. Inversely speaking, the increased ductility of the Assembly increases the building's natural frequency of the structure, which makes it more difficult for the building's frequency to be reached in a seismic event. The Assembly increases the ductility without increasing the displacement. The web assembly configuration can be adapted to individual reaction needs, both directional, amount of rotation and length of deflection (rotation), needed from the Assembly.

7 CONCLUSIONS

The primary structural parameters, which are used in the Assembly are that of member curvature and member confinement. If a member can be allowed or forced to move into curvature, each length of the member can be allocated a portion of the moment and shear in reverse, and the PΔ effect of the structure is minimized and controlled. This makes each web member act more efficiently along the member length and will tend to control forces from the Assembly to that being connected and dissipate energy accordingly.

The uses, which could benefit from the actions created in the Assembly are structural in nature but can go beyond the building environment. Additionally, this may include aeronautics, medical, athletics, and other incorporating mechanically loaded components, which could benefit by causing rotational displacement from linear forces as a form of energy transposition. The author is certain you can look around, where you currently stand and see numerous other connections and structures, which could benefit by the strengths generated from the use of the Assembly.

Acknowledgements

The views expressed herein are those of the author and do not necessarily reflect those of the advisors. The author is grateful to BRAE and for their advice and input during the preparation of this paper.

- Dr. Ali Abolmaali, Professional Engineer, Chair Department of Civil Engineering and Director of Center for Structural Engineering Research and Simulation, University of Texas at Arlington, Arlington, Texas (email: abolmaali@uta.edu).
- Dr. Bijan Mohraz, Professional Engineer, PhD advisor, Southern Methodist University, Dallas, Texas (email: bmohraz@engr.smu.edu).
- Dr. Roman Okelo, Professional Engineer (Structural), BR Architects & Engineers, Richardson, Texas 75080 (email: romano@brarchitects.com).

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