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Evaluation of Sloped Tubular Web RBS Moment Connections under Cyclic Behaviour

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Abstract— As the complex-shaped buildings become a popular trend, more researches are needed to embody those twisted and tilted shapes into real structures. The studies on the inclined column and beam connection that appears frequently in the complex-shaped structures are not sufficient in comparison to those on the conventional structures. So that the structural safety and the behavior. To evaluate the effects of a sloped connection considering an angle of deviation from orthogonal of 28^0, a tubular web reduced beam section (TW-RBS) moment connections is analyzed under cyclic loading. This proposed TW-RBS connection would be provided by replacing a part of the beam web with a steel tube at the expected location of plastic hinge. The load carrying capacity of this connection in deep beam is studied under sloping condition. Evaluation of sloped RBS moment connections with center of the ordinary RBS (flange cut) is perpendicular to the beam longitudinal axis of the beam and parallel to the column were already studied and found that the preferred configuration is the perpendicular one, not parallel. In this paper, the preferred configuration (perpendicular to the longitudinal axis of the beam) with TW-RBS is analytically tested under cyclic loading and compared with RBS connection.

Index Terms— cyclic behavior, Ductility, Finite Element Analysis , Reduced Beam Section (RBS), Reduced Web Section (RWS), Tubular Web Reduced Beam Section(TW-RBS), Steel Moment Frames,.

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1 Introduction

The RBS connection is one of the most popular and most economical type amongst post Northridge and Kobe connections.Number of analytical andexperimental studies have been performed onRBS moment connection to enrich poor momentconnections for existing steel moment frame.

InRBS the beam flange is trimmed away in theregion adjacent to beam-to-column connectionsat a certain distance away from the column faceto reduce the stress concentration developed inthe column panel zone. But in ordinary RBS moment connections, cutting beam flanges cause local and consequent global instabilities and resulting in premature failures. A new method; that is reduction can be introduced in the web of the beam, creating a reduced web section (RWS).RWS can achieved byreplacing beam web in a limited zone adjacent to the column face by corrugated plates , introducingperforations , openings in beam web etc. In this paper, web of the beam is reduced by providing TW-RBS connection in whichreplacing a part of the beam web with a steel tube at theexpected location of plastic hinge.

2 METHODOLOGY

As the complex-shaped buildings become a popular trend, more researches are needed to embody those twisted and tilted shapes into real structures.The studies on the inclined column and beam connection that appears frequently in the complex-shaped structures are not sufficient in comparison to those on the conventional structures.So that the structural safety and the behavior. To evaluate the effects of a sloped connection considering an angle of deviation from orthogonal of 28^0, a tubular web reduced beam section (TW-RBS) moment connections is analyzed under cyclic loading.

3 Proposed connection: TW-RBS

The configuration of the proposed connection is illustrated in Fig. 1. As shown in the figure, in a limited zone near the column face, the beam web is replaced with a vertical tubular section. The beam is connected to the column face by the Complete Joint Penetration (CJP) welding to develop the full capacity rigid connection.The connection proposed in this research is supposed to be in the reduced connection category. This RBS connection is called "Tubular-Web RBS connection", abbreviated as "TW-RBS". In this connection, the tubular web in the plastic hinge region improves the web stability condition. Due to the larger out-of-plane stiffness of the corrugated web. Moreover, the TW-RBS connection would lead to an enhanced the flange stability condition due to the smallerwidth to thickness ratio of the beam flange, as shown in Fig.1. According to the aforementioned features, it is expected that tubular web provides even a better condition than corrugated web connection in low-cycle fatigue, by changing sharp corners of angles to arc shape of the tubular web section then the stability and ductility of the beam with TW-RBS connection would be improved within the plastic hinge region.

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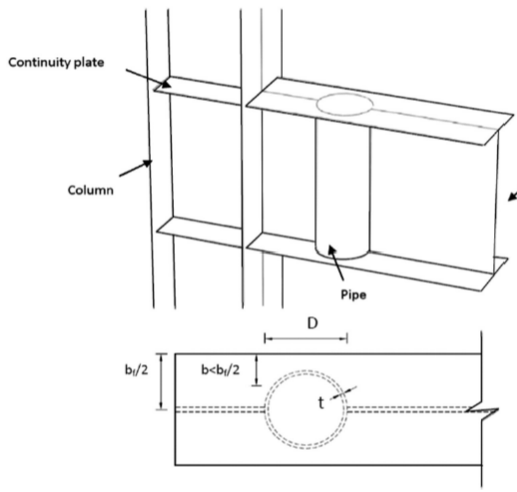

Fig.1 Proposed TW-RBS Connection

4 SLOPED RBS CONNECTION

Dong-won kim, Steven C. Ball et al. [1] have focused on the evaluation of sloped RWS moment connection. To evaluatethe effects of a sloped connection considering an angle of deviation from orthogonal of 28°, two reduced beam section (RBS) moment connections were cyclically tested with two configurations.One, in which center of the RBS is perpendicular to the longitudinal axis of the beam and the other in which, center of the RBS isparallel to the longitudinal axis of the column as shown in Fig.2 . Finite-element analysis wasalso done for the two configurations and they all concludedthat thepreferred configuration is the perpendicular one, not parallel. Finite element analysis shows that the stress demand is much lower for Configuration 2.

A comparison of the PEEQ index across the width of beam flange near the column face further confirms that it is more desirable to use Configuration 2 for the RBS section also it would reduce the strain demand at the heel location of the beam.

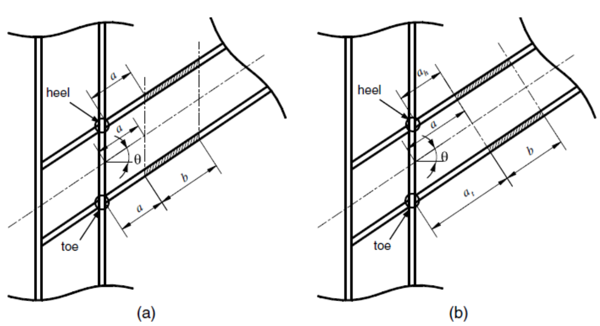

Fig.2 sloped RBS configurations: (a) Configuration 1: RBS parallel to column; (b) Configuration 2: RBS perpendicular to beam

In this paper, in the preferred configuration (RBS perpendicular to the longitudinal axis of the beam) RBS is replaced with TW-RBS and analytically tested under cyclic loading. The obtained details are compared with that of RBS connection.

5 GEOMETRY DETAILS

The overall dimensions and member sizes (W36 × 231 beam and W36 × 302 column) .These sections metthe prequalification limits of AISC 358. The beam framed to thecolumn with a slope of 28 degrees from the orthogonal. See Table 1for the mechanical properties obtained from tensile coupon tests. Fig. 3shows the arrangement. To simulate inflection points in the actual frame, the ends of the columns were mounted on a short section of W14 × 370 positioned to experience weak-axis bending. Two simulated lateral braces were provided for the beam and one lateral brace was provided for the column. TW-RBS connections are constructed by replacing a specified length of the beam web with a pipe.

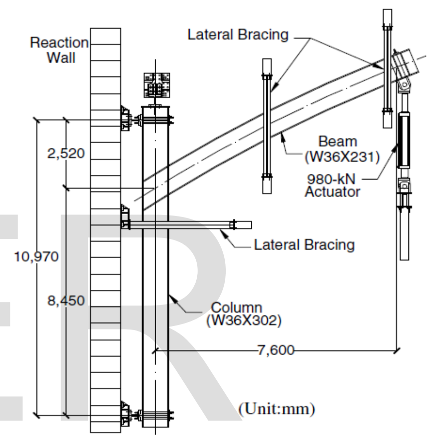

Fig.3 Overall Configuration the setup

The selected pipe has outside diameter of 323.9 mm and wall thickness of 6.3 mm. The horizontal distance from the face of column flange to start the pipe segment is 301.6mm.

TABLE 1
STEEL MECHANICAL PROPERTIES

Member	Steel grade	Yield stress (MPa)	Tensile strength (MPa)	Elongation (%)
Beam (W36 × 231)	A992	436.4	539.2	30
Column (W36 × 302)	A992	383.3	533.7	33

6 NUMERICAL STUDY

The ANSYS finite element software was used to model the specimens for nonlinear analysis.The fundamental assumptions made to idealize steel mechanical properties are including: Young's modulus of 2x 105 MPa , Poisson's ratio of 0.3. SOLID from ANSYS library was used for 3-D finite element modelling of the RBS moment connection. The column was assumed as fixed connected at both the ends and at the joint beam to column element connection is configured as fully restrained.

A displacement control loading was applied onthe tip of the beam by imposing cyclicdisplacement based on AISC seismic provision.

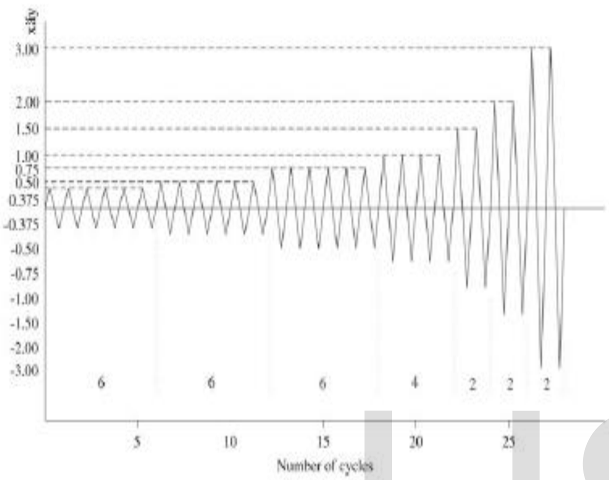

Fig.4Loading Protocol

The total story drift angle was calculated by dividing the exerted displacement by the column height. The loading history consisted of six cycles, each of 0.375%, 0.5%, and 0.75% total story drift angle, sequentially. The next four cycles were 1% story drift, followed by two cycles each of successively increasing drift percentages (i.e., 2, 3, 4... %).

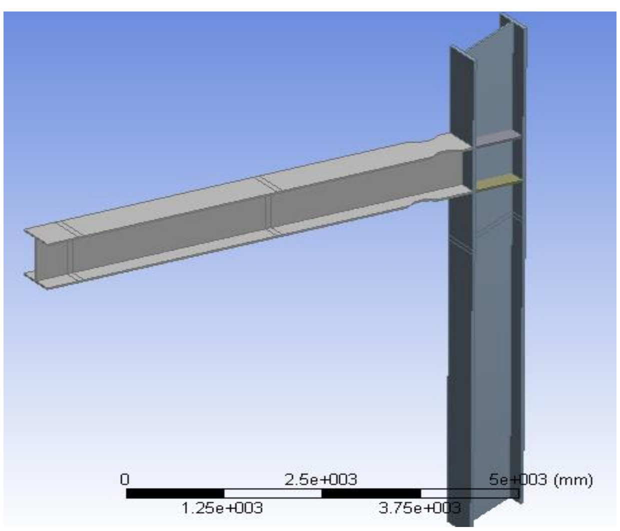

Fig.5 FEA model of Configuration 2 with RBS (angle of deviation from orthogonal of 28°)

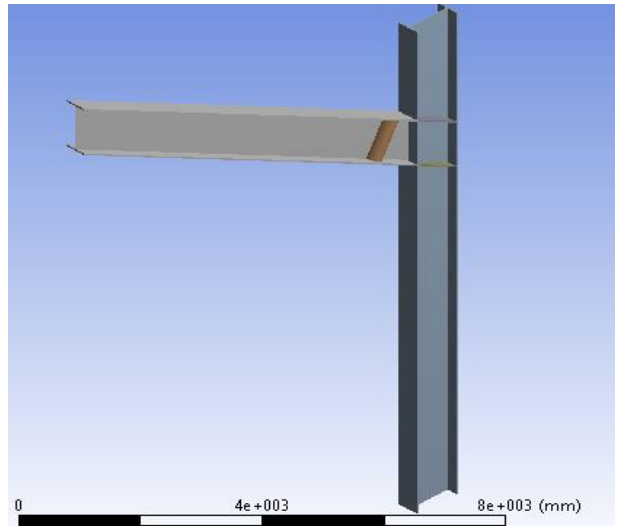

Fig.5 FEA model of Configuration 2 with RBS (angle of deviation from orthogonal of 28°)

7 RESULT

7.1Stress Distribution

The Von Mises Stress distribution of two models were shown below. Generally for ordinary welded connections (OWC) the concentrated stress occur in the panel zone of the column face. But here it can be seen that for both the models concentrated stress occurs in the region of beam were reduction is provided. In RBS, beam flange is reduced but in TW-RBS, reduction is done in the beam web both at the location of plastic hinge.

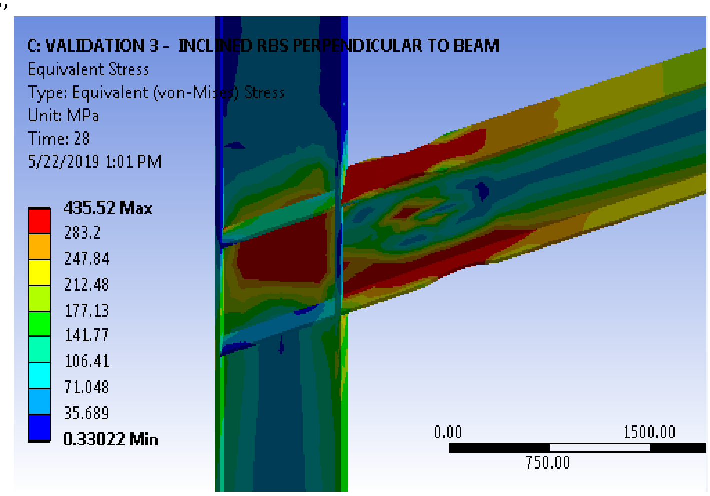

Fig.7 Von Mises Stress distribution of sloped RBS

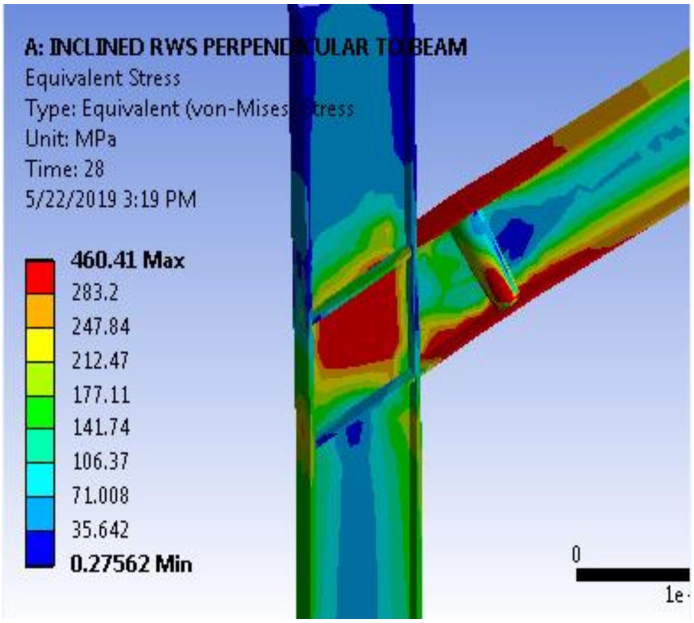

Fig.8 Von Mises Stress distribution of sloped TW-RBS

Here in both cases stress is concentrated at the reduced region. In sloped moment connection with RBS perpendicular to the longitudinal axis of the beam, maximum stress distribution is obtained as 435.52N/mm^{2}and that for TW-RBS perpendicular to the longitudinal axis of the beam is obtained as 460.41N/mm^2. The stress distribution is approximately similar for both cases.

By comparing the von Mises stress contours at 4% drift; (Fig.7 and Fig.8) in sloped moment connection, replacing RBS in configuration 2 with TW-RBS at the location of plastic hinge gives similar results for stress distribution, ie; TW-RBS performs as similar as ordinary flange cut RBS connection in case of stress distribution.

7.2Hysteresis Behavior

The total energy dissipated by each specimen during a complete excursion of 0.04 rad total rotation is show in figures below.

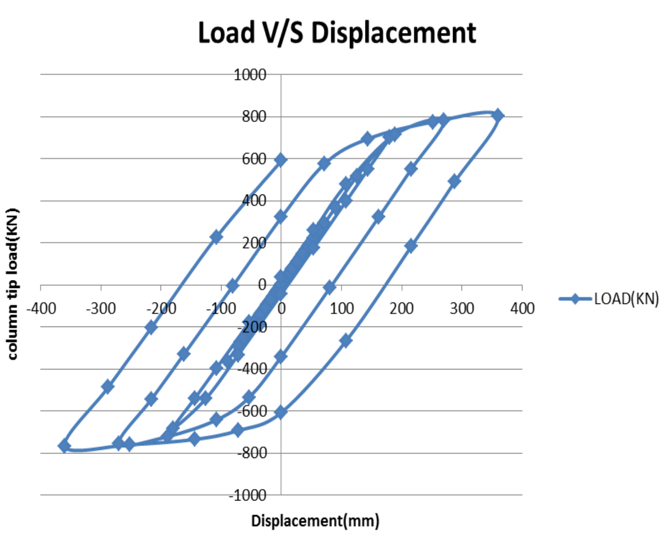

Fig.9 Hysteresis loop of sloped RBS

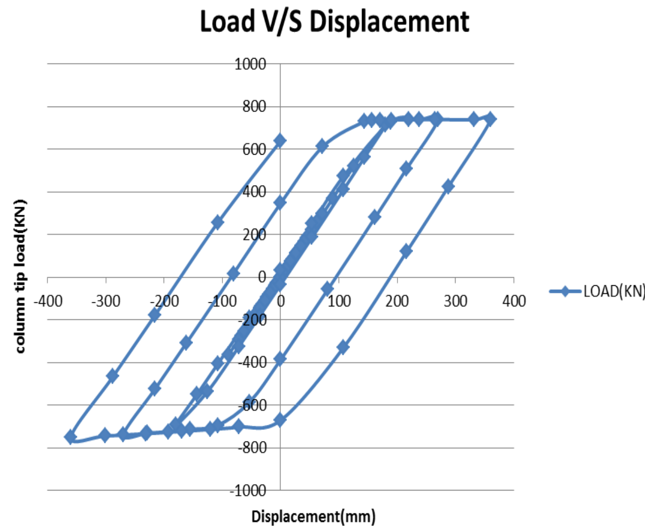

Fig.10 Hysteresis loop of sloped TW-RBS

From the hysteresis behavior of both the models, the area of hysteretic loops gradually increased and residual deformations were observed with the increase of displacement after yielding.Comparing the hysteresis loop of sloped TW-RBS connection with that of sloped RBS,the behavior is almost same.

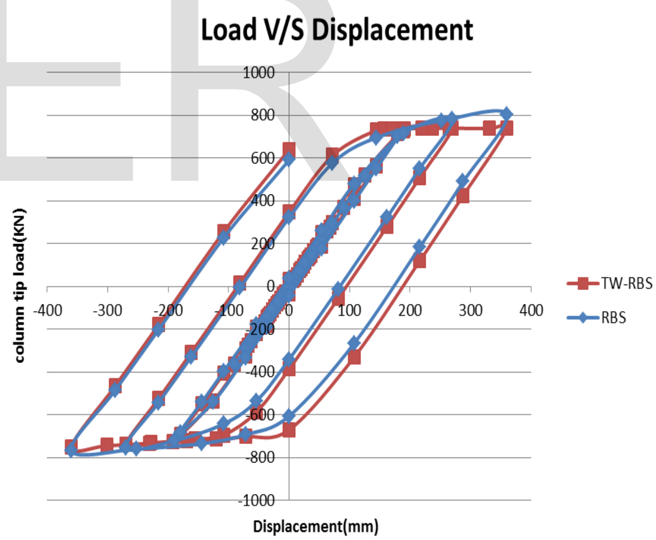

Fig.10 Comparing cyclic responses of sloped TW-RBS to those of sloped RBS

From Fig.10, in which the hysteresis behavior of both the models are compared and the result obtained as both sloped Connection where the reduction is done perpendicular to the longitudinal axis of the beam with TW-RBS and RBS shows almost same behavior.So that the reduction of beam done with ordinary RBS can be replaced with TW-RBS in sloped moment connection.

The load carrying capacity of sloped moment connection with the reduced web either done with ordinary cut RBS or with TW-RBS shows almost similar behavior in case of total energy dissipation. The load carrying capacity of both the reduced cases with configuration2 , that is the reduction is perpendicular to the longitudinal axis of the column shows approximately similar behavior. The load carried by the two models during a complete excursion of 0.04 rad total rotation is similar and that we can replace RBS with TW-RBS in sloped moment connection.

In TW-RBS connection, due to the larger out-of-plane stiffness of the corrugated web. Moreover, the TW-RBS connection would lead to an enhanced the flange stability condition due to the smaller width to thickness ratio of the beam flange**.** Also tubular web provides even a better condition than corrugated web connection in low-cycle fatigue, by changing sharp corners of angles to arc shape of the tubular web section then the stability and ductility of the beam with TW-RBS connection would be improved within the plastic hinge region.

8 DISCUSSION

To achieve the above objectives, a detailed literature review on reduced beam sections were first carried out. In ordinary RBS moment connections, cutting beam flanges cause local and consequent global instabilities and resulting in premature failures. By replacing ordinary cut RBS with TW-RBS, the above mentioned problem can be eliminated. From the Von Mises stress distribution diagram, both specimens shows excellent transformation of concentrated stress from the column face to reduced section with more rotation capacity. From both stress distribution and hysteresis behavior, sloped moment connection with TW-RBS performs almost similar as that with ordinary flange cut RBS.

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