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Experimental Investigation of Steel Connections

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Abstract- **- Experimental results and comparative study has proven to be core for the foundation and development of structural and Earthquake engineering. In the recent past, various research has been carried out from full scale to scaled model prototypes on the evaluation of weld and bolt steel connections. Reversal stresses within milliseconds make beam-column connections most vulnerable to lateral loads when exposed. It would result in failure and catastrophe if not designed and erected correctly. The capability to transfer forces through the joint is the index to keep the structure safe and sound to avoid progressive collapse in the case of buildings. It is clear now that failure of beam-column joint will ultimately lead to structural damage, so the importance is self-evident.**

Index Terms— Bold Steel Connections, weld steel connections, Earthquake.

I. INTRODUCTION

Steel is an alloy of elements of Carbon (C) and Iron (Fe) mixed in different combinations per the requirements of its applications based on both usage and strength. Steel Frame Structure is such structures typically comprised of vertical columns and horizontal beams connected either by rivets, bolts, or weld in a rectangular-shaped grid. Structure steel is mainly designed, fabricated, and erected in compliance with the standards of AISC (American Institute of Steel Construction). Steel structures are used across Industrial, High Rise, Warehouse, Residential and Temporary structures. Steel structures proved to be an upper hand over other types of construction in more significant projects because of their various advantages [1-3].

It is friendlier to Environment as it is purely recyclable, harming our Mother Nature and ecosystem. But to most, its best advantage is constructability as steel structures can be erected faster, consuming the time for clients and enhancing construction productivity Erection in all seasons is possible with minimum waste to the construction site. Light weight ratio has also been another advantage as it consumes a lot of space compared to RC structures. Steel structures cost about 7-8% less than RC Frame structures. However, most of the research addresses their code, standards, and labor method of work. In Pakistan, which lies in the developing countries, Nationwide steel structures are being designed by designers for many small and big projects, and the trend for steel structures is increasing as compared to previous decades [4,5].

A portion of the beam flanges is selected and trimmed in that region adjacent to the beam-column connection. A part of the beam flanges is determined and cut in that region adjacent to the beam-column link. However, the latter is not practical in Pakistan, Bolted Steel Construction Lightweight Steel Construction. To reduce moment capacity at a specific distance from the point of the column, a large forces strain will occur in a desirable location. It will go under large inelastic deformation, force yielding, and hinge formation at that reduced beam portion. Various methods fabricate steel structures, but the most common among them is Conventional Steel Construction (Welded Connections) [6,7].

II. LITERATURE REVIEW

Welded connection of the steel moment-resisting frame (SMRF) will be protected by reducing the beam section. The reduced beam section is very important to get the high flexibility of the seismic system. A reduced beam section is instrumental in achieving the high performance of the structure under earthquake loading. By reducing the beam section, we are forcing the beam not to fail 1st at the connection joint.

III. METHODOLOGY OF RESEARCH

A full-scale model of the 2-D steel frame model was used for the prototype. The model will be erected and tested in a Quasi-static manner at Structural Analysis Lab in the civil engineering department, UET Peshawar. This study will focus on the overall performance of structures exposed to strong Earthquake lateral forces. The full-scale model was used as it fulfills the suitability of the structural analysis Lab. Performance criteria check to be applied for evaluating the performance structures. BCP-07 shall be strictly implemented and followed for designing multistory buildings.

The Design philosophy followed here for the model is a strong beam and weak column. SBWC approach is to prevent any serviceability failure for flooring and mainly for this experimental study to damage the connection and prevent members. The advantage is the results in fair section members' sizes, thus preventing overdesign cost. In a moment-resisting structure modeled while considering energy dissipation zones, this approach effectively helps to contribute to all section members and connections fully. This further leads to reducing the P delta effect on the structure.

IV. MODEL DESCRIPTION

A simple single-story two-bay steel frame structure is designed and studied in this experimental study. Previously the same system was tested for reinforced structure for lateral quasi-static loading. Structural dimensions have 18ft by 18ft bay and 12ft height of the design. Performance of the system of the center 2D frame is studied for SMRF (Steel Moment Resisting Frames) as the structure is symmetrical and has equal dimensions in both directions. Therefore, similar loads were distributed on the center frame.

V. LOAD COMBINATIONS

Loads are considered as per BCP-07 (Building code of Pakistan) and ASCE7-05 (American Society for Civil Engineers). Dead, Live, and self-weight are considered. Dead Load is determined from a concrete slab of 6 above the steel frame. Concrete has a unit weight of 150lbs/ft2. Live Loads are 40 lbs./ft2. Self-weight of the beam is also considered. The basic design procedure was considered 1.2D+1.6L, but meanwhile, for seismic analysis, an approach of 1.2D+0.5L was followed.

VI. SEISMIC DESIGN FACTOR

We considered other risk factors for modeled structure as elaborated in BCP-07, e.g., Importance Factor, Seismic Reduction Factor, Occupancy category, and soil category. A system is a residential place, so as per BCP-07 Importance factor allocated is 1 per seismic design spectrum for zone 4. The seismic reduction factor was assigned a value of 8.5. The eccentricity ratio was 0.05 on X-axis for all diaphragms, whereas time was set to 0.035secs.

VII. MATERIAL AND MODELING OF STRUCTURE

Structural steel for sections here is considered A36 Grade 36 for all structure members. e.g., beams and columns. A36 has a yield of up to 250N/mm2; the bolts used are A725 high tensile bolts. The Beam section was proposed to be I-section. See Tab. I and Tab. II, III and IV, and V. Figure A shows the basic structure.

Table I: Loading Combinations

1) Loads and Loading Combination
2) Self-Weight Concrete Unit Weight 150lbs/ft
3) Floor Finish and Live Load (roof Floor)
4) 60psf and 40psf
5) Load Combination as per BCP-07
6) U=1.4 Dead load
7) U=1.4 Dead load +1.6 Live Load
8) U=1.1(0.9 Dead load ± 1.0 Earthquake load)
9) U=1.1(1.2 Dead+.5 Live Load±1.0 Earthquake load)

Table II: Seismic Coefficients

Seismic Factor	values
1) Zone 4	0.04
2) Importance Factor	1
3) Eccentricity in X-axis	0.05
4) Seismic Reduction Factor	8.5
5) Seismic Source Type	B
6) Distance to Source (km)	15

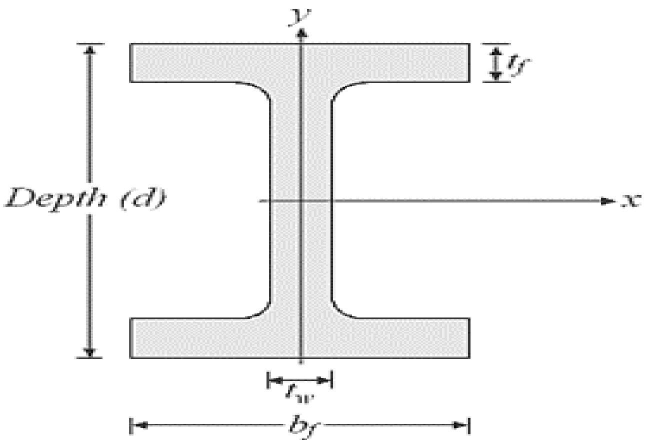

FIGURE A: Proposed section Beam

Table III: A36 steel Properties

	Description	Value
1)	Section (in×lbf/ft)	12×36
2)	Area (in^2)	10.3
3)	d (in)	12.50
4)	bf (in)	6.560
5)	tf (in)	0.520
6)	tw (in)	0.300
7)	Ixx (in^4)	285
8)	Zxx (in^3)	45.6
9)	Kxx (in)	5.25
10)	Iyy (in^4)	24.5
11)	Zyy (in^3)	7.47
12)	Kyy (in)	1.54

VIII. PROPOSED SECTION FOR DESIGN

After ETABS and SAP2000 for the best appropriate steel sections that would resist the applied loading, after a detailed check on more than 100 steel sections, two areas were finally selected for experimental work. Detailed analysis of a design procedure adopted (see Fig. B).

Table: IV: I-Section Beam Properties

	Description	Value
1)	Material Grade	36
2)	Weight Per Unit Volume	0.4Kip/ft2
3)	Mass Per Unit Volume	0.0152 k/ft3
4)	Modulus of Elasticity	29000000
5)	Poisson Ratio	0.3
6)	Coefficient of thermal expansion	6.5×10-6
7)	Shear Modulus	11153846
8)	Minimum Yield Stress, Fy lb/ft2	36000
9)	Minimum Tensile Stress Fu lb./ft2	58000
10)	Expected Yield stress Fye lb/ft2	54000
11)	Expected Tensile Stress Fue lb/ft2	63800

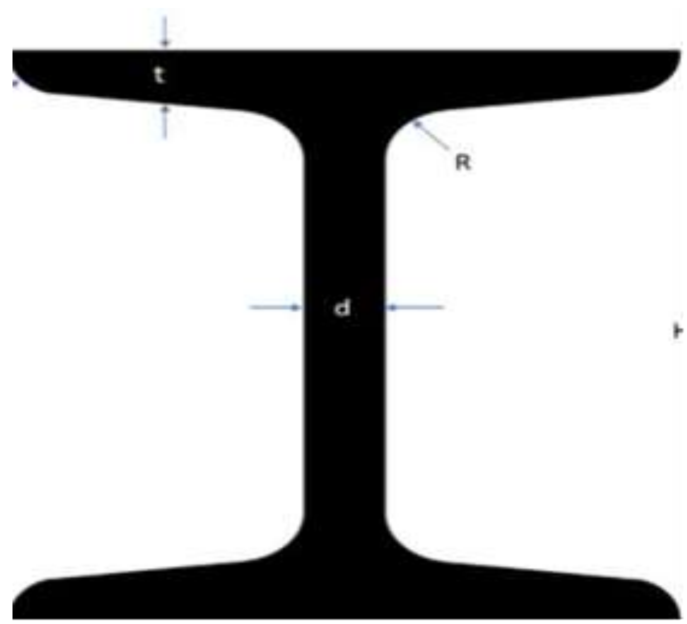

Figure B: Beam Section.

IX. OUR DESIGN

we design our section based on trial and error with the help of an excel sheet and select the best suitable parameters for our areas.

Table V: Beam section dimensions

NAMES	DIMENSIONS (in)
Flange thickness	0.63
flange length	6
Web thickness	0.472
web length	12.74
Beam length	120
Area	13.57

A. DESIGN OF DOUBLE PLATES.

No. of plates: 2
Thickness of plates= 0.75”
Size or dimension = 13.25” x 7.134”

B. DESIGN OF CONTINUITY PLATES:

Continued plates whose thickness was almost equal to the beam flange thickness. The thickness of the beam flanges is 0.94 inches. One-inch-thick continuity plate is used..
The number of plates: 4.
Thickness of plates
Size or dimension = 7.134” x 3.823”

C. DESIGN OF COLUMN PLATES:

No. of plates: 2
The thickness of plates= 0.75”
Size or dimension = 12” x 12”
No. of bolts=8

D. DESIGN OF STIFFENER PLATES:

No. of plates: 1
The thickness of plates= 0.125”
Size or dimension = 6.5” x 6.5”

E. DESIGN OF CONTINUITY PLATES:

No. of plates: 1
The thickness of plates= 0.25”
Size or dimension = 11.5” x 4.5”

The testing was carried out on a full-scale prototype because of the lab facilities available. Cyclic loading was applied to the sample. Certain loading protocols (see Figs. 2-4) were followed during the testing of the model.

Figure 1: Initial samples.

Figure 2: Plates Cutting.

Figure 3: Welding and Strain Gauges.

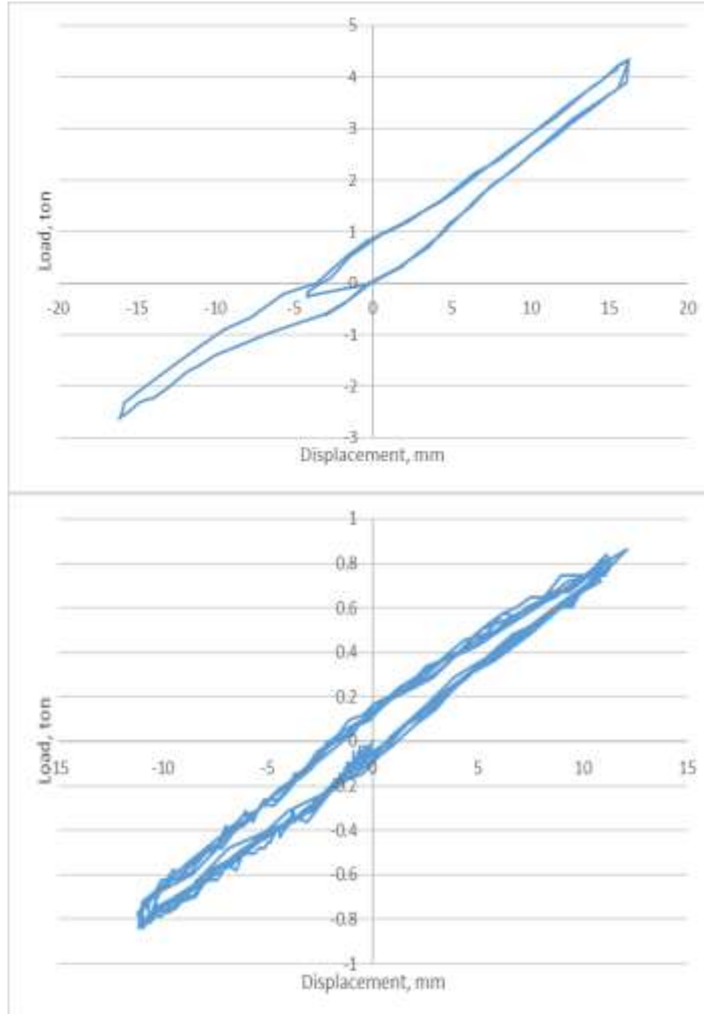

Figure 5: Graphs of 10.9mm and 16 mm respectively.

Figure 4: Lab Test Setup.

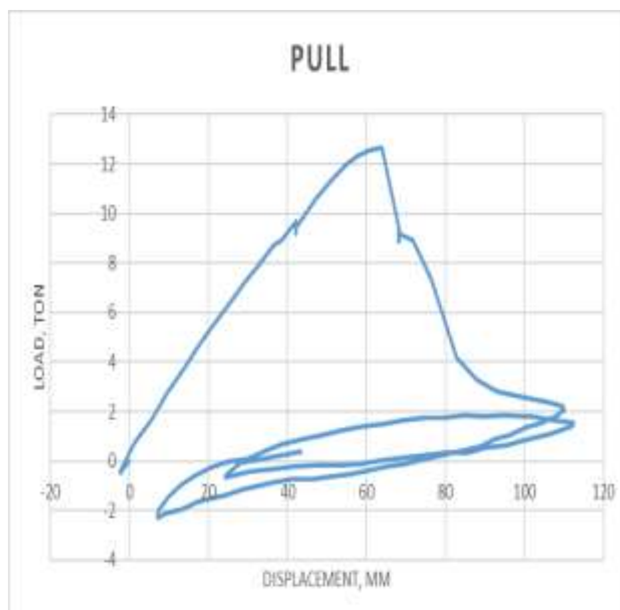

Figure 6: Pull graph.

X. CONCLUSIONS

The connection must be strong to distribute the stresses to a specific desired location up to the length of the beam. The pressures will not be on the connection point to create a strong column weak beam, and such a mechanism will result in the formation of plastic hinges, which will provide the performance of the RBS connection. Our weld used in connection failed instead of reduced beam section, so the main reason is our sample is over strength, and total stresses act on the link, and hence weld failed. The other reason is using local welding in which local rods are used and hence failed in the middle of loading phenomena (see Fig. 5 and Fig. 6).

Welded connection failed due to the poor quality of their joints, poor qualification of the welder, and use of unnecessary primary and additional welding material.

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