# Increasing the Strength of Existing Building using Steel Jacketing in Seismic Zone

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***Abstract****;-*

*This research project will give a brief presentation about earthquake resistant design and the methodology about seismic evaluation and rehabilitation of existing structures by steel jacketing. It also provides certain aspects of computer software modeling against seismic loads and shows the necessity of seismic upgrading in existing building.*

*The seismic evaluation process consists of investigating if the structure meets the defined target structural performance levels. The main goal during earthquakes is to assure that building collapse doesn't occur and the risk of death or injury to people is minimized and beyond that to satisfy post-earthquake performance level for defined range of seismic hazards. Also seismic evaluation will determine which are the most vulnerable and weak components and deficiencies of a building during an expected earthquake. The seismic rehabilitation process aims to improve seismic performance and correct the deficiencies by increasing strength, stiffness or deformation capacity and improving connections. Thus, a proposed retrofit implementation can be said to be successful if it results an increase in strength and ductility capacity of the structure which is greater than the demands imposed by earthquakes.*

## INTRODUCTION

In order to prevent loss of human life and property due to future earthquakes, the steel jacket retrofit has been used as a method to enhance the shear strength and ductility of square reinforced concrete columns in existing buildings. On the seismic behavior of square RC columns retrofitted by the steel jacket based on many researchers conducted in Japan. Main items described in this report are design formula to predict deformation capacity of the retrofitted columns. The proposed methods and formula are verified by many experimental results of the retrofitted RC column specimens tested by Japanese researchers. It should be emphasized that the characteristic of the proposed methods and formula is their applicability to wide ranges of parameters such as material strength, wall thickness of the steel jacket, aspect ratio of the column, and magnitude of axial load.

Steel jacketing refers to encasing the section with steel plates and filling the gap with non-shrink grout. It is a very effective method to remedy the deficiencies such as inadequate shear strength and inadequate splices of longitudinal bars at critical locations. But, it may be costly and its fire resistance has to be addressed. In practice the most commonly used strengthening technique is by steel strips and angles (a variety of steel). Steel Jacketing has been widely used in European Countries in the past centuries. Since the 1995 Hyogoken-Nanbu earthquake steel jackets are extensively used to enhance the shear capacity and ductility of the square reinforced concrete columns.

Sakino & Sun (2000) produced a state-of-art report on the seismic behavior of the retrofitted square RC columns based on the researches conducted in Japan. They established the stress strain relation of the concrete confined by steel jacket, described the method to evaluate the ultimate bearing strength and shear strength of the retrofitted columns under combined compression, bending & shear and produced the design formulae to calculate the deformation capacity of the retrofitted column. RuizPinilla, Pallarés, Gimenez&Calderón (2014) experimented on 20 full scale interior beam column joints (Figure 2) to determine the behavior of steel jacketing as a strengthening system for reinforced concrete framed structures. The main objective ofthis research was to determine the behavior of the strengthened beam column joints designed originally for only gravity load. They have carried out the experiment with strong beam and weak columns under gravity load and cyclic load. In order to reach the conclusion author have prepared load displacement envelope of all the specimens. It concluded that steel jacketing prevent column failure, increase the bending strength of column and the failure section is transferred to the next weakest zone. Belal, Mohamed & Morad (2015) investigated the behavior of RC column strengthened with steel jacket technique. Seven Specimens were divided in two control un-strengthened specimen and five strengthened specimens. Author worked on three variables, namely the shape of the main strengthening system, shape and size of the batten plates. The specimens were placed in the loading system between jack head and steel frames. Author has carried out FE modeling of the experimental program in ANSYS 12.0.Comparison between the experimental results and FE results were carried out. Author have prepared load vs deflection curve for each specimen for experimental program as well as FE modeling. It have found that FE modeling had a good agreement with the experimental program. From this study Author have concluded that steel jacketing technique increased the load carrying capacity upto 20% and also observed that the mode of failure of the control specimens were brittle but strengthening with steel jacket changed the failure mode to more ductile.

***Advantage of Steel Jacketing***

- Establish method
- Availability of code
- Readily Available Material
- Faster construction

***Disadvantages of Steel Jacketing***

- Bulky set-up
- Labor intensive
- Drilling & bolting damage structure
- Corrosion problem
- Change aesthetics

***Steel Jacketing***

Local strengthening of columns has been frequently accomplished by jacketing with steel plates. A general feature of steel jacketing is mentioned in Table no. 1.

**Table No. 1: Details of Steel Jacketing.**

| | |
|---|---|
| Steel plate thickness | • At least 6 mm. |
| Height of jacket | • 1.2 to 1.5 times splice length in case of flexural columns.  Full height of column in case of shear columns |
| Shape of jackets | • Rectangular jacketing, prefabricated two L-shaped panels The use of rectangular jackets has proved to be successful in case of small size columns up to 36 inch width that have been successfully retrofitted with %" thick steel jackets combined with adhesive anchor bolt, but has been less successful on larger rectangular columns. On larger columns, rectangular jackets appear to be incapable to provide adequateconfinement |
| Free ends of jackets bottom clearance. | • Welded throughout the height of jacket, size of weld1"<br>• 38 mm (1.5 inch), steel jacket may be terminated above the top of footing to avoid any possible bearing of the steel jacket against the footing, to avoid local damage to the jacket and/or an undesirable or unintended increase in flexural capacity. |
| Gap between steel jacket and concrete column Size of anchor Number of anchor bolts | • 5 mm fill with cementations grout.<br>• 25 mm in diameter and 300 mm long embedded in 200 mm into concrete column.<br>• Bolts were installed through pre-drilled holes on the steel jacket using an epoxy adhesive.<br>• Two anchor bolts are intended to stiffen the steel jacket and improve confinement of the splice. |

***Design Example:***

***Beam with Steel Jacketing***

Due to corrosion of reinforcement moment carrying capacity and share strength of beam is reduces. To increase the flexural strength of beam extra steel is required. Following is the data given. Calculate extra steel for required moment. (Assume existing Reinforcements is zero due corrosion for analysis purpose).

Data:- Mu= 47 kN.m, Ast = 125 wide x 8 thick = 1000 mm2, fck = 12 N/mm2, fy = 250 N/mm2, b = 230mm, d=360 mm, D = 400mm

**Solution:-**

0.87xFyxAst = (0.87x250x125) 0.36X12X230 = 166.06 mm 0.36XFckXb

Xu = Mu = 0.66 fyAst (d- 0.42 Xu) = 0.66 x 250x 1000 (360-0.42x 166.06) = 47.89 x106 N.mm > 47kN.m ……..safe Hence provide 125 x 8 mm thick steel plate

Vu = 85kN Area of steel provided = 2 x100 x 6 = 1200mm2 Load taken by steel plate = 0.4 x fy x Area of steel plate 120 kN> 85 kN….. Safe Provide 100 x 6 mm thick Steel plate

**Figure 1 Revised Section of Beam**

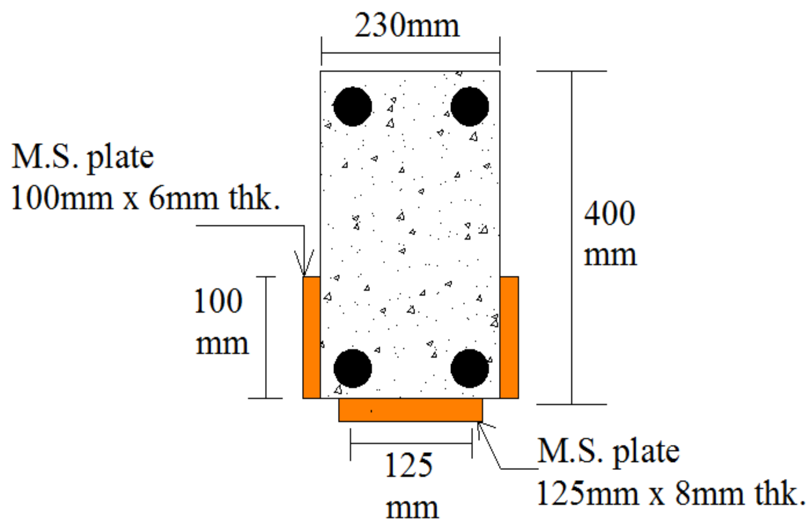


**Table 2 Ast Required for Beam Strengthening**

| Sr. No. | Floor | Beam No. | M.R. Required. (kN.m) | Ast Provided (mm2) | M.R. Provided (kN.m ) |
|---|---|---|---|---|---|
| 1 | **Plinth Beam** | B10,B8,B12 | 47 | 1000 | 48 |
| | | B1 to B7, B9,B11, B13 to B45 | 33 | 800 | 40.15 |
| 2 | **First Floor** | B1 to B45 | 40 | 800 | 40.15 |
| 3 | **Second Floor** | B1 to B26, B29, B30, B31, B32, B33, B34, B36, B37, B38, B41, | 27 | 600 | 31.49 |
| | | B27,B28,B35,B36,B37, B38,B39,B40 | 24 | 450 | 24.39 |
| 4 | **Third Floor** | B1to B31 | 33 | 800 | 40.15 |
| | | B32,B33,B34,B41,B42, B43,B44,B45 | 23 | 450 | 24.39 |
| 5 | **Roof Beam** | B1 to B45 | 22 | 450 | 24.39 |

***Column with Steel Jacketing***

Due to corrosion of reinforcement Axial Force carrying capacity of column is reduces. To increase the axial strength of column extra steel is required. Following is the data given. Calculate extra steel for required axial force. (Assume existing Reinforcements is zero due corrosion for analysis purpose)

Data:-

P = 1037 kN, Mx = 5 kN.m, My = 25 kN.m,

Fy = 250 MPa, Fcd = 165 MPa (assume)

Solution:
Pu = 0.4 x fck x Ac + 0.67 x fy x Ast
= 0.4 x 12 x ((230x450)-(1608)) + 0.67 x 250 x 0
Pu = 489.06 kN< 1037 kN ….…not safe Load deficiency = 1037 – 489.06 = **547.94 kN**

**Step: - 1**

Required Area = Fcd3320.54 = 3320.54 mm2,
Area of one Angle = No. of Angle = 4 = 830.21 mm2

**Step 2**

1.05xKxL

KL/r == 102.88
Stress reduction factor = 0.439 (by interpolation)

**Step: - 3**

Partial Safety factor for steel = 1.15

Fcd=0.439xFy/1.15 = 95.60

Pd = Area of angelxFcd/1000xNo. Of angel, = 824.48≥ 547.94……….safe

**Step: - 4**

***Design Moment Calculation***

beta = 1 (for plastic & compact sec.) Geometry
S1 = width of column – 2 x (minimum of L1 & L2) = 80 …along width S2 = Depth of column – 2 x (maximum of L1 & L2) = 150 ….along Length

Leaver Alarm along X = length of column – 2 x Cxx = 343.6 mm
Leaver Alarm along Y = width of column – 2 x Cyy = 197.8 mm

**Step: - 5**

2 x area of angle x fcd = 412.24 kN
Mxd = Fmax x L.A. x Along Y = 81.54 kN.m
1000
Myd = Fmax x L.A. x Along Y = 141.64 kN.m
1000
(P/Pd)+(Mx/Mxd)+(My/Myd) = 0.902 < 1 ……Safe

**Step: - 6**

***Design of Single Lacing Along Longer Leg***

Angle of inclination = 45 0
Width of Lacing = 50mm, Thick of lacing = 8 mm, length of lacing = 636 mm, Effective length of lacing (0.7x length) = 445.2 mm
a = 900 mm
Radius of gyration of individual member (r) = minimum of rxx&ryy = 19.9 mm, a/r = 45.22 < 50…… safe
Shear force in column (2.5% axial force) = 2.5/100 x P = 13.7 Shear force at each junction = 13.7 / L2 = 0.85
Size of weld = 6 mm
Ultimate stress of weld = 250 N/mm2 Partial safety factor for site weld = 1.5 Design strength of weld = 0.40 kN/mm
Total weld length required = shear force at each junction/ Design strength of weld = 2.09 mm Weld length provided = 15 mm

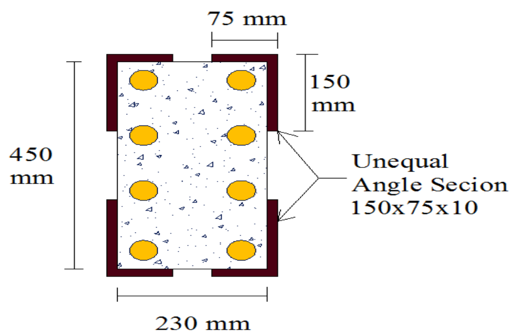


**Figure 2 Revised Section of column**

**Table 3 Column Strengthening using Steel Plate for Required Capacity of 72.8645 Kn, Column no. C1 At Ground Floor**

| | | | |
|---|---|---|---|
| **Description of member characteristics** | L= Length of Column | 450 | mm |
| | B = Breadth of Column | 230 | mm |
| | H = Height of column, | 2.9 | m |
| | fck = Cube strength of concrete, | 20 | $N/mm^2$ |
| | fy = yield strength of reinforcement, | 500 | $N/mm^2$ |

| | | | |
|---|---|---|---|
| | rc = Corner, radius of curvature | 30 | mm |
| | Existing column reinforcement % | 1.1 | % |
| | Existing column Capacity | 1177.83 | kN |
| | Required column Capacity | 72.8645 | kN |
| | Enhanced Required column Capacity | 120.226425 | kN |
| | Additional Force enhancement Required, Pn | -1057.60358 | kN |
| | **Maufacture's reported FRP system properties** | | |
| | $f_y$= Yield strength of steel Plate | 310 | N/mm$^2$ |
| | $E_s$ = Modulus of Elasticity | 250000 | N/mm$^2$ |
| Step 1 | **Provided Steel Plate** | | |
| | Length of steel Plate provided | 800 | mm |
| | Thickness of steel plate | 6 | mm |
| | $A_{ss}$ =Area of structural steel plate provided | 4800 | mm |
| Step 2 | **Increase in axial capacity after fibre wraping** | | |
| | $0.87*f_y*A_{ss}$, $P_{inc.}$ = | 1294.56 | kN |
| | Design Check for Adequacy | SAFE | |
| | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ***Schedule of STEEL PLATE*** | ***Provide*** | ***steel*** | ***plate of*** | ***800*** | ***mm length &*** | ***6.00*** | ***mm, thick*** |
| ***C1 GROUND FLOOR*** | | | | | | | |

## CONCLUSION

- It is advisable to monitor the building health periodically by taking a professional opinion. Non-destructive testing should be carried out if buildings found deteriorated and damaged over time. Comparative result of three techniques is tabulated below.
- As per steel jacketing is concern it's give very good method of increasing longitudinal steel, but very costly method.
- Steel Retrofitting and FRP retrofitting techniques is most suitable as per architectural intent in case of concrete jacketing architect does not agree because of increase in size of members.

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