STRENGTHENING OF BEAM COLUMN AND SLAB

Strengthening of concrete structures must be considered when the existing structure deteriorates or any alteration to the structure has to be made due to which the structure may fail to serve its purpose. Concerns must be taken to existing materials, often in deteriorated condition, loads during strengthening and to existing geometry. In some cases it can also be difficult to reach the areas that need to be strengthened. When concrete structural strengthening is to be undertaken all failure modes must be evaluated. Strengthening a structure for flexure may lead to shear failure instead of giving the desired increased load bearing capacity. It should also be noted that not only the failure mode of the strengthened member is important. If a critical member in a structure is strengthened, another member can become the critical one. Because of changed stiffness in an undetermined structural system the whole structure must be investigated. The strengthening should also designed with consideration to minimize the maintenance and repair needs. When a strengthening is designed the consequences from loss of strengthening effectiveness by fire, vandalism, collision etc. must in addition be considered.

The existing documentation of the structure is often very poor and sometimes even wrong. It might be necessary to redesign the structure with the probable former codes that were active when the structure was built. This can give enough knowledge about the structural mode of action, otherwise field investigations must be undertaken to provide an understanding of the structure. The design of a strengthening however must fulfill requirements in the codes of today. It is not only the financial and structural aspects that should form the basis for decisions of strengthening method, but environmental and aesthetic aspects must also be considered.

STRENGTHENING OF BEAMS

Reinforced concrete beams need strengthening when the existing steel bars in the beam are unsafe or insufficient, or when the loads applied to the beam are increased. In such cases, there

are different solutions that could be followed: **I-ADDING REINFORCEMENT STEEL BARS TO THE MAIN STEEL WITHOUT INCREASING THE BEAM'S CROSS SECTIONAL AREA** This solution is carried out when the reinforcing steel bars are not capable to carry the stresses applied to the beam. The following steps should be followed: 1. The concrete cover is removed for both the upper and lower steel bars. 2. The steel bars are well cleaned and coated with an appropriate material that would prevent corrosion. 3. Holes are made, in the whole span of the beam under the slab, as shown in Fig.1, 15-25cm apart, a diameter of 1.3cm and extend to the total width of the beam.

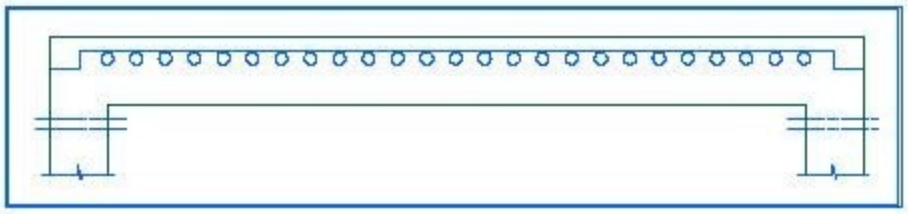

Fig.1: Holes in the span of a beam

4. The holes are filled with an epoxy material with low viscosity and installing steel connectors for fastening the new stirrups. 5. Steel connectors are installed into the columns in order to fasten the steel bars added to the beam. 6. The added stirrups are closed using steel wires and the new steel is installed into these stirrups. 7. The surface is then coated with a bonding epoxy material. 8. The concrete cover is poured over the new steel and the new stirrups. The previous steps are illustrated in Fig 2.

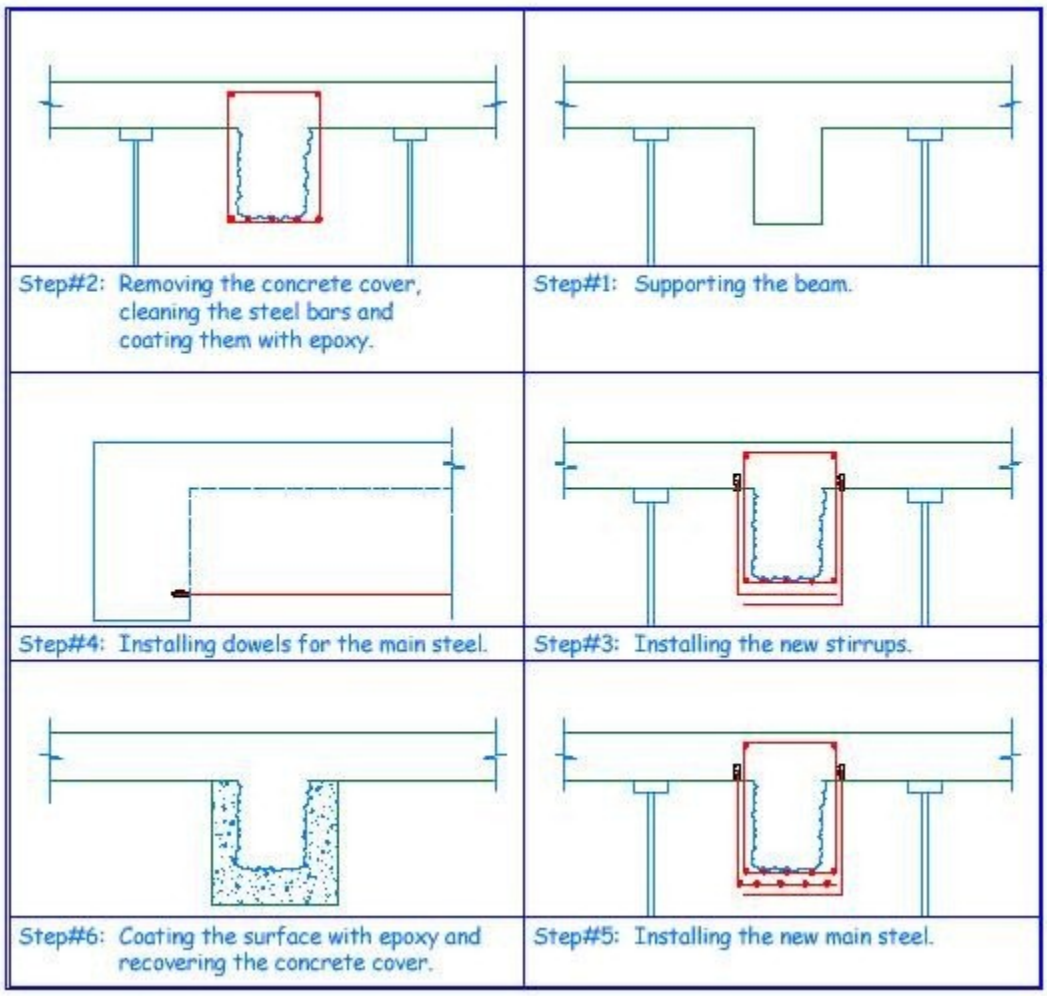

Fig.2-

Strengthening a beam without increasing cross sectional area.

II-INCREASING BOTH THE REINFORCING STEEL BARS AND THE CROSS - SECTIONAL AREA OF CONCRETE This solution is chosen when both the steel and concrete are not able to carry the additional loads applied to the beam. In such cases the following steps should be followed as in *Fig 3*. 1. Removing the concrete cover, roughing the beams surface, cleaning the reinforcement steel bars and coating them with an appropriate material that would prevent corrosion. 2. Making holes in the whole span and width of the beam under the slab at 15-25cm. 3. Filling the holes with cement mortar with low viscosity and installing steel connectors for fastening the new stirrups. 4. Installing the steel connectors into the columns in order to fasten the steel bars added to the beam. 5. Closing the added stirrups using steel wires and the new steel is installed into these stirrups. 6. Coating the concrete surface with an appropriate epoxy material that would guarantee the bond between the old and new concrete, exactly before pouring the concrete. 7. Pouring the concrete jacket using low shrinkage concrete.

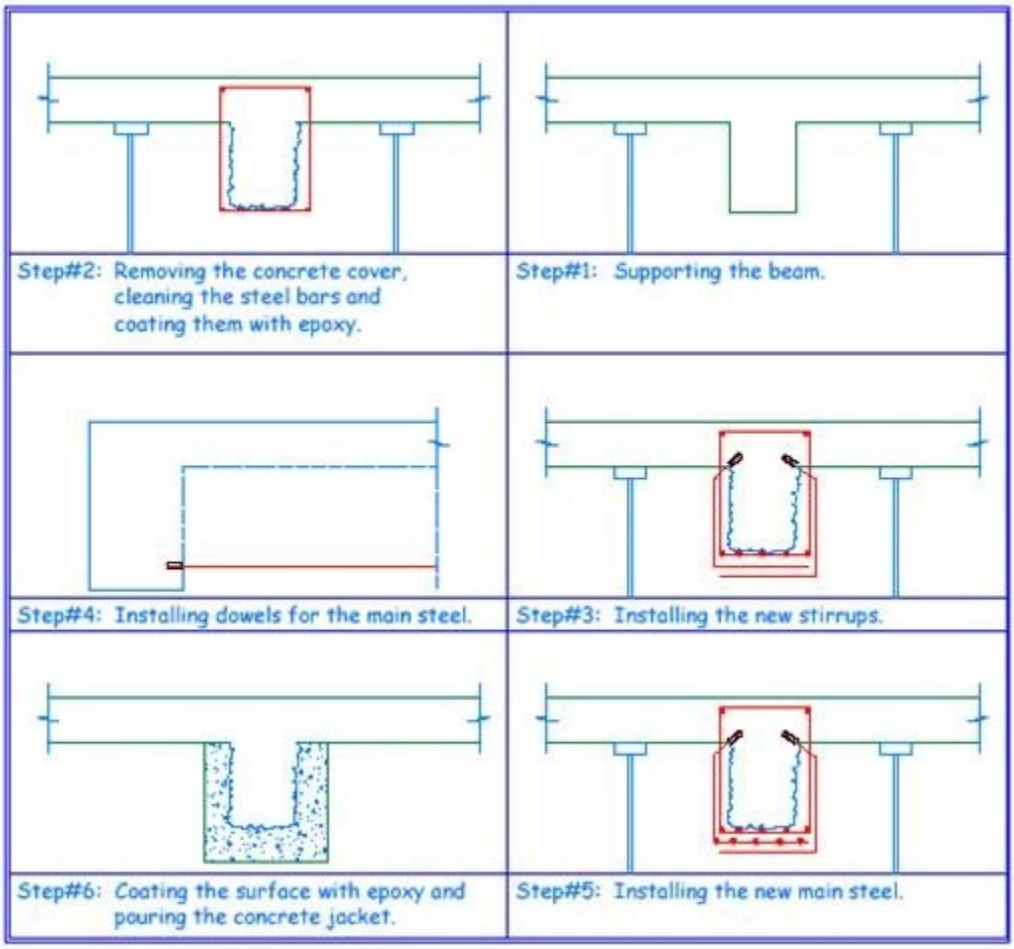

Fig.3:

Strengthening of beam by increasing the cross-sectional area and bars

III-ADDING STEEL PLATES TO THE BEAM When it is required to strengthen the beam's resistance against the applied moment or shear stress, steel plates are designed with the appropriate size and thickness. Then those plates are attached to the beam as follows: 1. Roughing and cleaning the concrete surfaces where the plates will be attached. 2. Coating the concrete surfaces with a bonding epoxy material. 3. Making holes in the concrete surfaces and plates. 4. Putting a layer of epoxy mortar on top of the plates with a 5mm thickness. 5. Attaching the steel plates to the concrete using bolts. The previous steps are illustrated in Fig 4.

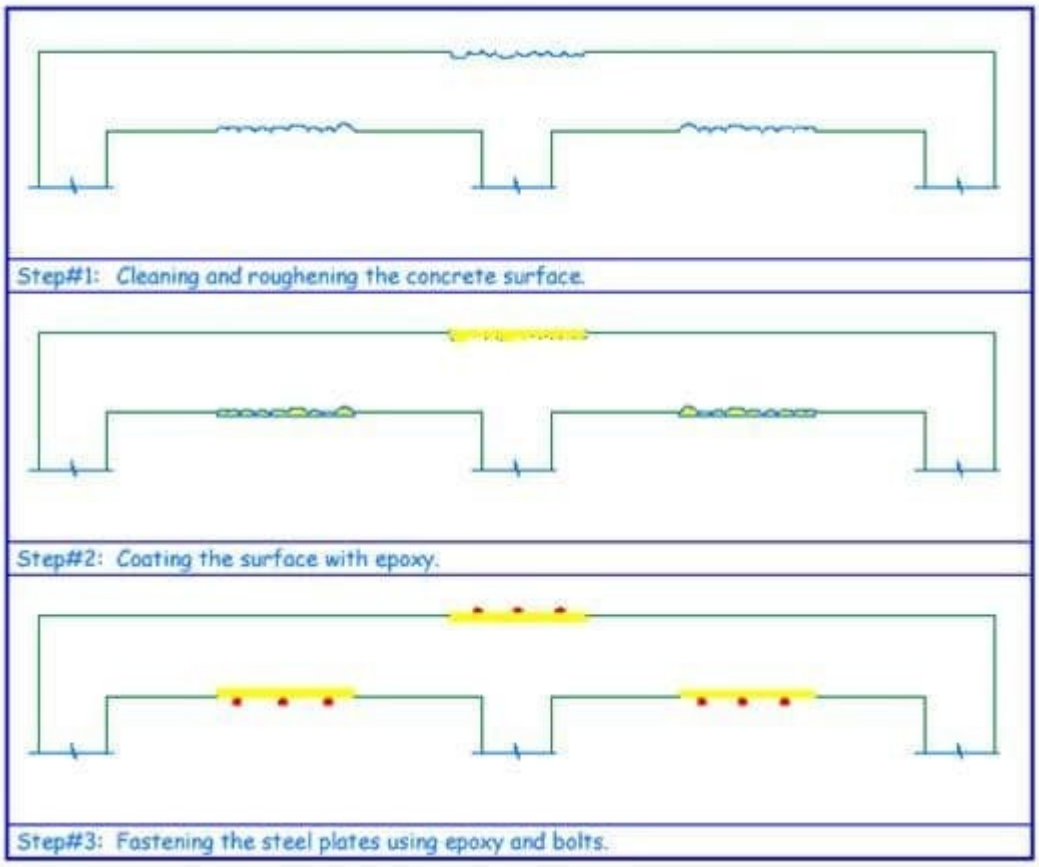

Fig.4: Strengthening of Beam by adding steel plates

In some cases, it is needed to reduce the load on the beam that needs strengthening before implementing the previous steps, either partial or complete unloading. This is made by putting steel beams on top or below the concrete beams, as shown in *Fig5*.

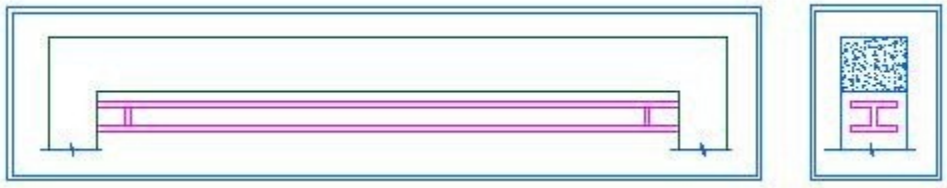

Fig.5: Reducing the load on the beam using steel beam.

The following photos were taken during strengthening an existing building; they present the practical method of implementing some strengthening techniques.

Strengthening a beam , slab and column.

Strengthening a beam and Slab.

Jacketing a beam by increasing bars and cross section.

Strengthening by steel plates.

Column strengthening is a process used to add or restore ultimate load capacity of reinforced concrete columns. It is used for seismic retrofitting, supporting additional live load or dead load that not included in the original design, to relieve stresses generated by design or construction errors, or to restore original load capacity to damaged structural elements. There are several techniques which are used to strengthen reinforced concrete columns like reinforced concrete jacketing, steel jacketing, and FRP confining or jacketing.

When strengthening of R.C. Column is needed?

1. The load carried by the column is increased due to either increasing the number of floors or due to mistakes in the design.
2. The compressive strength of the concrete or the percent and type of reinforcement are not according to the codes' requirements.
3. The inclination of the column is more than the allowable.
4. The settlement in the foundation is more than the allowable.

Strengthening Techniques for R.C. Columns

1. Reinforced Concrete Jacketing

It is one of the techniques used to improve or restore capacity of reinforced concrete column. The size of the jacket and the number and diameter of the steel bars used in the jacketing process depend on the structural analysis that was made to the column.

Reinforced Concrete Jacketing Process

1. Initially, reduce or eliminate loads on columns temporarily if it is required. This is done by putting mechanical jacks and additional props between floors.
2. After that, if it is found out that reinforcements are corroded, the remove the concrete cover and clean the steel bars using a wire brush or sand compressor.
3. Then, coat the steel bars with an epoxy material that would prevent corrosion.
4. If reducing loads and cleaning reinforcement is not needed, the jacketing process begin by adding steel connectors into the existing column.
5. The steel connectors are added into the column by making holes 3-4mm larger than the diameter of the used steel connectors and 10-15cm depth.
6. The spacing of new stirrups of the jacket in both the vertical and horizontal directions should not be more than 50cm.
7. Filling the holes with an appropriate epoxy material then inserting the connectors into the holes.
8. Adding vertical steel connectors to fasten the vertical steel bars of the jacket following the same procedure in step 5 and 6.
9. Installing the new vertical steel bars and stirrups of the jacket according to the designed dimensions and diameters.
10. Coating the existing column with an appropriate epoxy material that would guarantee the bond between the old and new concrete.
11. Pouring the concrete of the jacket before the epoxy material dries. The concrete used should be of low shrinkage and consists of small aggregates, sand, cement and additional materials to prevent shrinkage. Steps of reinforced concrete jacketing are illustrated in Fig. 1.

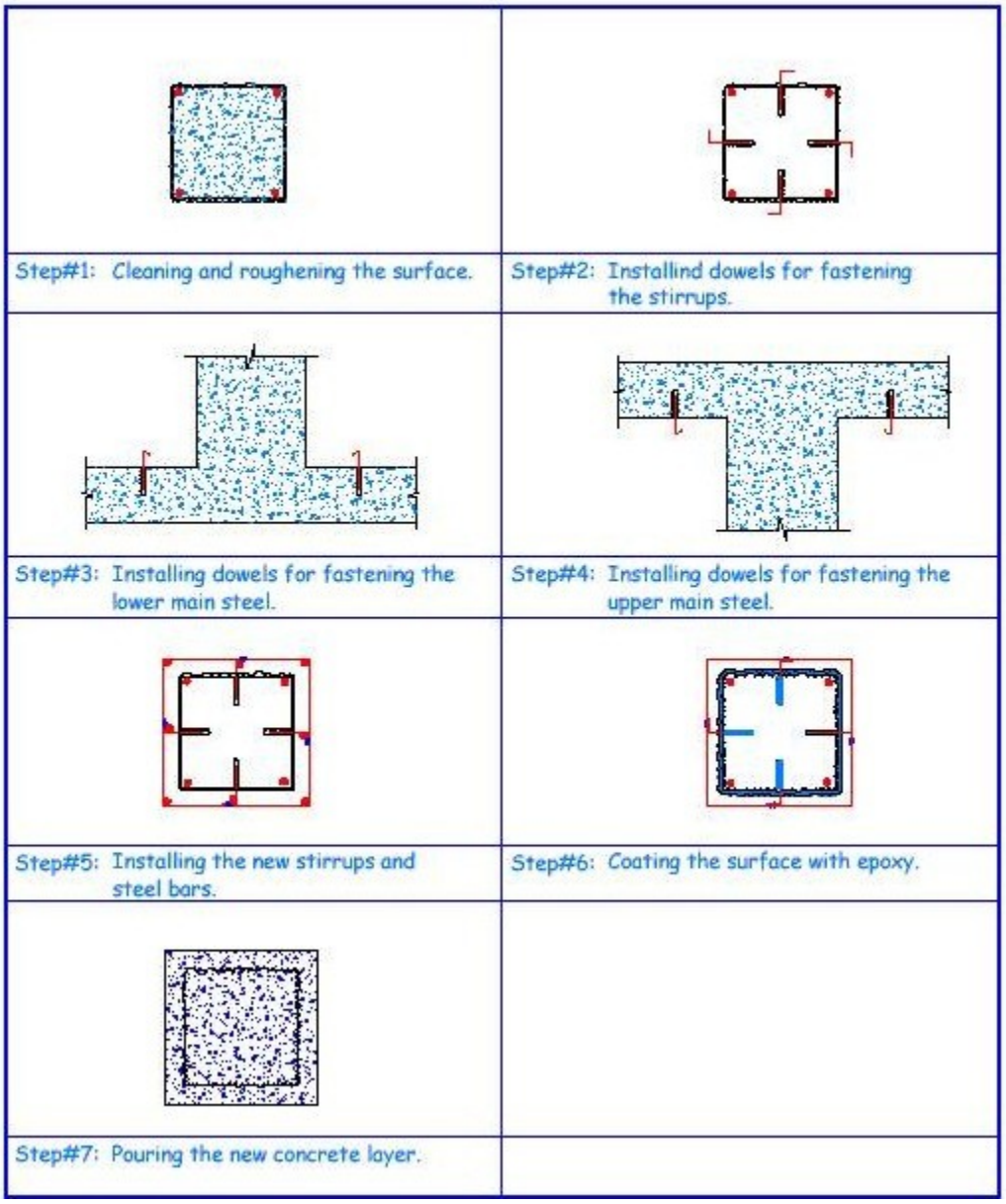

Fig. 1: Increasing the Cross-sectional Area of Column by RC Jacketing

2. Steel Jacketing

This technique is chosen when the loads applied to the column will be increased, and at the same time, increasing the cross sectional area of the column is not permitted.

Steel Jacketing Process

1. Removing the concrete cover.
2. Cleaning the reinforcement steel bars using a wire brush or a sand compressor.
3. Coating the steel bars with an epoxy material that would prevent corrosion.

4. Installing the steel jacket with the required size and thickness, according to the design, and making openings to pour through them the epoxy material that would guarantee the needed bond between the concrete column and the steel jacket.
5. Filling the space between the concrete column and the steel jacket with an appropriate epoxy material.

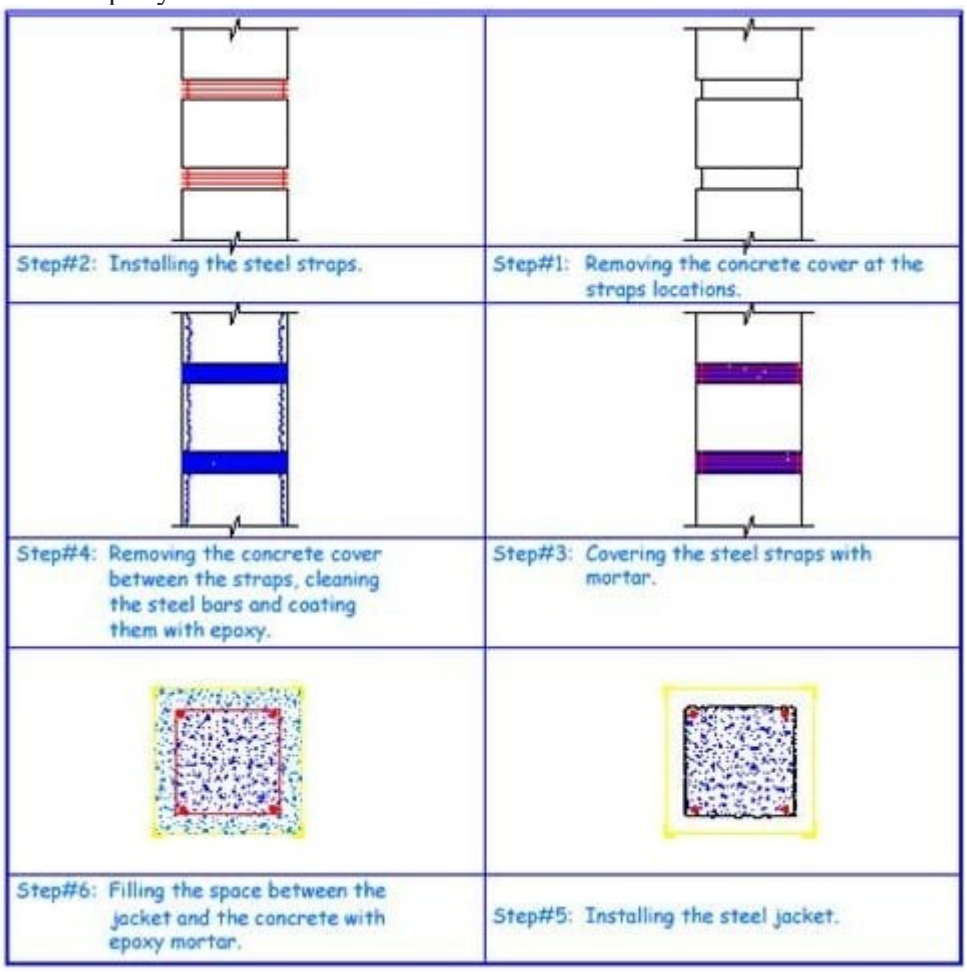

Fig. 2: Increasing the cross-sectional area of column by steel jacketing

In some cases, where the column is needed to carry bending moment and transfer it successfully through the floors, one should install a steel collar at the neck of the column by means of bolts or a suitable bonding material.

Fig. 3: Column strengthened with steel angles

Fig. 4: Welding steel jacket

Fig. 5: Welding process

Placement of Steel Jacket After Welding process ended