Shear Strengthening of Column Using Ferrocement Jacketing

Shruti Fasale[1], Pramod V. Kharmale[2]
[1]Dept of Civil Engineering
[2]Professor, Dept of Civil Engineering
[1, 2] G.H.Raisoni College of Engineering & management, Chas, Ahmednagar, Maharashtra,India

Abstract- *Ferrocement is a new material consisting of closely spaced wire meshes and cement mortar which is very effective in strengthening work. The simple idea is that it undergoes large strains in the neighborhood of the strengthening and the magnitude of straining depends on the distribution and sector of reinforcement throughout of concrete. In this paper the strengthening of reinforced concrete columns using ferrocement laminates are studied. In this study, the use of ferrocement as an outside detention to concrete samples is investigated. The usefulness of detention is achieved by comparing the behavior of retrofitted samples with that of conventional samples. The strengthened columns have performed better in cracking behavior, reduction in deflection and increased in the ultimate load. In this book the parameters, which critically influence the moment carrying capacity of the ferrocement laminates is also identified and discussed*

Keywords- ferrocement,RCC core steel composite column, RC column,JACKETING

I. INTRODUCTION

1.1 GENERAL

Jacketing is the most popularly used method for strengthening of building columns and beams. The most common types of jackets are steel jacket, reinforced concrete jacket, fibre reinforced polymer composite jacket, jacket with high tension materials like carbon fibre, glass fibre etc.

1.2 NEEED

Jacketing is needed for the following purposes:

1. To increase the strength of deteriorated structure to increase their life.
2. To increase the seismic capacity of the structure.
3. To increase concrete confinement by transverse fibre reinforcement, especially for circular cross-sectional columns,
4. To increase shear strength by transverse fibrereinforcement.
5. To increase flexural strength by longitudinal fibre reinforcement provided. They were anchored at critical sections. Transverse fibreshould be wrapped all around the entire circumference of the members possessing close loops sufficiently overlapped or welded in order to increase concrete confinement and shear strength.

II. SCOPE AND OBJECTIVE

All the structures have their own life span after certain life period the structure start to deteriorate and that structure is not about to take load moreover and structure get failed. But if the structure goes through structural repair procedure its strength can be increased and there is no requirement for the demolish by which we can save time as well as money also.

III. METODOLOGY

3.1 THEROTICAL CONTENT

The primary concern of a structural engineer is to successfully restore the structures as quickly as possible. Selection of right materials, techniques and procedures to be employed for the repair of a given structures have been a major challenges. Jacketing is easy to execute and effective as per the type of jacketing technique.

3.2DIFFERENT TECHNIQUES OF JACKETING

There are several types of jacketing depending on the material and component to be repaired. Some of the important techniques are given below:

3.2.1 R.C.C. COLUMN JACKETING

R.C.C. Jacketing is the most popularly used for strengthening of building columns &Beams. The most common types of jackets are reinforced concrete jacket. The main purposes of jacketing are increases the member size significantly. This has the advantages of increase the member stiffness and is useful where deformation is to be controlled. If columns in the building are found to be slender, RC jacketing provides a better solution for avoiding buckling problems.

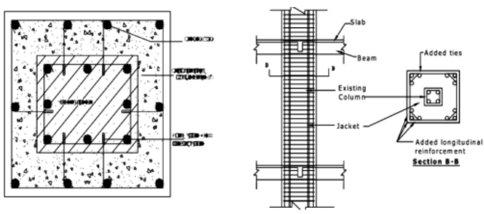


Figure No.3.2.1 (a): Construction Technique for Column Jacketing [4]

Figure No. 3.2.1(b): Column Jacketing

ADVANTAGES OF CONCRETE JACKETING

1. To increase the shear & flexural capacity of Beam.
2. To improve the compressive strength & Moment caring capacity of column.
3. Ease in construction.
4. Easily available material.

DISADVANTAGE OF JACKETING

1. The sizes of the sections are increased and the free available usable space becomes less.
2. Huge dead mass is added.
3. Requires adequate dowelling to the existing column.
4. Longitudinal bars need to be anchored to the foundation and should be continuous through the slab.
5. Requires drilling of holes in existing column, slab, beams and footings.
6. Placement of ties in beam column joints is not practically feasible.
7. The speed of implementation is slow.

3.2.2STEEL JACKETING

Local strengthening of columns has been frequently accomplished by jacketing with steel plates. A general feature of steel jacketing is mentioned in Table 3.2.2.

Table No. 3.2.2: Details of Steel Jacketing [4]

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 upto 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 adequate confinement.
Free ends of jackets bottomclearance	• Welded throughout the height of jacket, size of weld1" • 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	• 25 mm fill with cementations grout.

column Size of anchor Number of anchor bolts	• 25 mm in diameter and 300 mm long embedded in 200 mm into concrete column. • Bolts were installed through pre-drilled holes on the steel jacket using an epoxy adhesive. • Two anchor bolts are intended to stiffen the steel jacket and improve confinement of the splice.

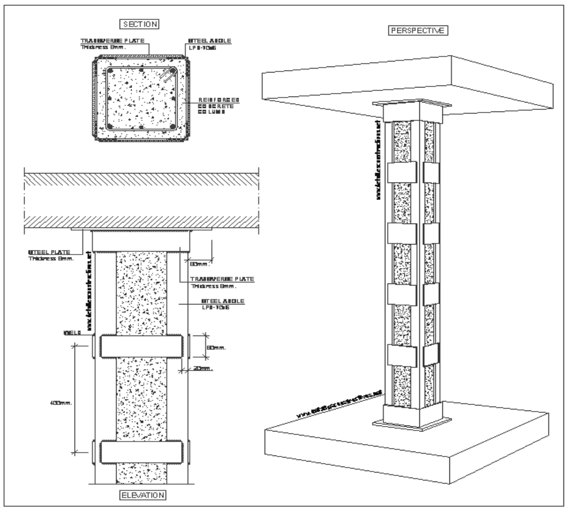


Figure 3.2.2: Steel Plate Jacketing

3.2.3R.C.C. BEAM JACKETING

Jacketing of beams is recommended for several purposes as it gives continuity to the columns and increases the strength and stiffness of the structure. While jacketing a beam, its flexural resistance must be carefully computed to avoid the creation of a strong beam-weak column system. In the retrofitted structure, there is a strong possibility of change of mode of failure and redistribution of forces as a result of jacketing of column, which may consequently causes beam hinging. The location of the beam critical section and the participation of the existing reinforcement should be taken into consideration. Jacketing of beam may be carried out under different ways, the most common are one-sided jackets or 3- and 4-sided jackets. At several occasions, the slab has been perforated to allow the ties to go through and to enable the casting of concrete. The beam should be jacketed through its whole length. The reinforcement has also been added to increase beam flexural capacity moderately and to produce high joint shear stresses. Top bars crossing the orthogonal beams are put through holes and the bottom bars have been placed under the soffit of the existing beams, at each side of the existing column. Beam transverse steel consists of sets of U-shaped ties fixed to the top jacket bars and of inverted U-shaped ties placed through perforations in the slab, closely spaced ties have been placed near the joint region where beamhinging is expected to occur (figure no. 3.2.3). The main features of reinforcement details of beam jacketing are given in table 3.2.3.Although those guidelines can give a rational basis for practical design, research still needs to address critical aspects in the behavior of jacketed elements. The change in behavior in jacketed elements, whose shear span/depth ratios are significantly reduced, due to their jacketing, needs to be clarified.

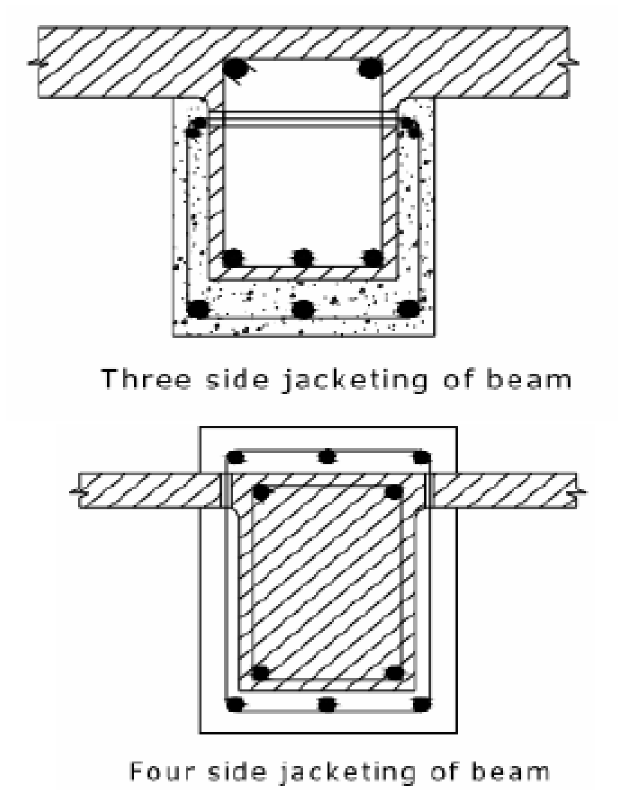


Figure 3.2.3: RCC Beam Jacketing[4]

Table 3.2.3: Reinforcement of beam jacketing [4]

3.2.4FIBRE REINFORCED POLYMER

Fibre Reinforced Polymer (FRP) materials have been widely applied in construction and structural rehabilitation due to their high strength, stiffness-to-weight ratio, high corrosion resistance, the ability to form and to shape to the existing structure, and the application process which is relatively fast and easy.

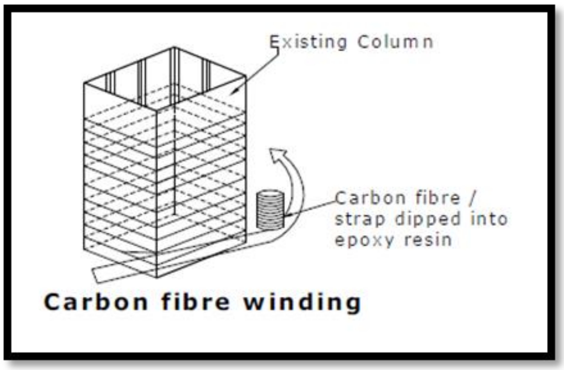


Figure 3.2.4(a): FRP Jacketing [4]

Figure 3.2.4(b): FRP of circular column

ADVANTAGES OF FERROCEMENT MATERIAL

1. Corrosion Resistance
2. Light Weight
3. Ease of Installation
4. Less Finishing
5. Less Maintenance
6. High tensile strength
7. Storage & Transportation is easy

DISADVANTAGES OF FERROCEMENT MATERIAL

1. Temperature & moisture effect
2. Lack of Design Code
3. Lack of Awareness
4. Skill supervision is required

IV. DESIGN AND ANALYSIS

4.1 GENERAL

R.C.C. Jacketing is the most popularly used for strengthening of building columns & Beams. IS15988-2013 gives the guidelines for the analysis of Reinforced concrete jacketing of beam and column.

4.2REINFORCED CONCRETE JACKETING OF COLUMNS [7]

Reinforced concrete jacketing improves column flexural strength and ductility. Closely spaced transverse reinforcement provided in the jacketim proves the shear strength and ductility of the column. The procedure for reinforced concrete jacketing is as follows:

The column size and section details are estimated for *P* and *M* as determined above.

The existing column size and amount of reinforcement is deducted to obtain the amount of concrete and steel to be provided in the jacket.

The extra size of column cross-section and reinforcement is provided in the jacket.

Increase the amount of concrete and steel actually to be provided as follows to account for losses.

$A_c = (3/2)A_c'$ and
$A_s = (4/3)A_s'$

Where

*A*c and *A*s = actual concrete and steel to be provided in the jacket; and

*A'*c and *A'*s = concrete and steel values obtained for the jacket after deducting the existing concrete and steel from their respective required amount.

The spacing of ties to be provided in the jacketin order to avoid flexural shear failure of column and provide adequate confinement to the longitudinal steel along the jacket is given as:

$$s = \frac{f_y}{\sqrt{f_{ck}}} \frac{{d_h}^2}{t_j}$$

Where
*f*y = yield strength of steel,
*f*ck = cube strength of concrete,
*d*h = diameter of stirrup, and
*t*j = thickness of jacket.

If the transfer of axial load to new longitudinal steel is not critical then friction present at the interface shall be relied on for the shear transfer, which shall be enhanced by roughening the old surface. Dowels which are epoxy grouted and bent into90° hook shall also be employed to improve the anchorage of new concrete jacket

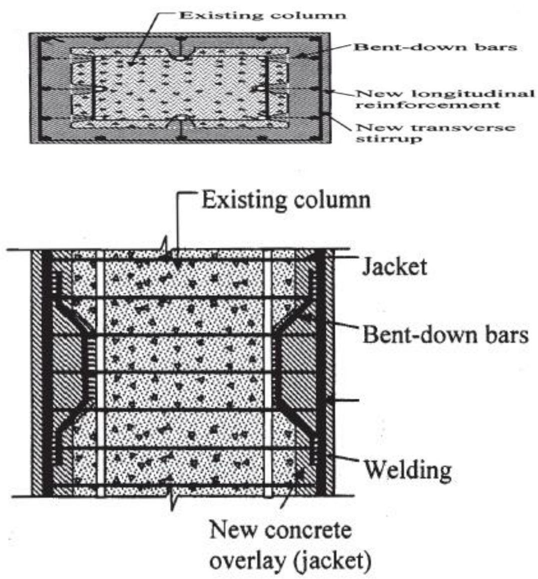


Figure 4.2: Reinforced concrete jacketing [7]

The minimum specifications for jacketing columns are:

a) Strength of the new materials shall be equal or greater than those of the existing column. Concrete strength shall be at least 5 MPa greater than the strength of the existing concrete.
b) For columns where extra longitudinal reinforcement is not required, a minimum of 12mm bars in the four corners and ties of 8mm @ 100 c/c should be provided with 135° bends and 10mm leg lengths.
c) Minimum jacket thickness shall be 100 mm.
d) Lateral support to all the longitudinal bars shall be provided by ties with an included angle of not more than 135°.
e) Minimum diameter of ties shall be 8 mm and not less than one-third of the longitudinal bar diameter.
f) Vertical spacing of ties shall not exceed 200 mm, whereas the spacing close to the joints within a length of ¼ of the clear height shall not exceed 100 mm. Preferably, the spacing of ties shall not exceed thethickness of the jacket or 200 mm whichever is less.

4.3DESIGN OF RCC COLUMN JACKETING AS PERIS 15988:2013

Height of Column= 3 m, Width (b) = 230 mm, Depth (D) =450 mm, Ultimate Axial Load (P)=1037 kN, UltimateMoment (M) = 25 kN.m, Concrete grade by NDT=12 N/mm2, d'=effective cover = 50 mm.,
Reinf. Provided: 8-16Ø = 1608 mm2

Solution:-

Due to corrosion area of reinforcement is reduces
For analysis purpose steel area is neglected
Pu = 0.4 x fck x Ac + 0.67 x fy x Asc
Pu = 0.4 x 12 x ((230x450)-(1608)) + 0.67 x 415 x 0
Pu = 489.06 kN< 1037 kN …..…not safe
Load deficiency = 1037 – 489.06 = **547.94 kN**
Reinforcement required
d'/D = 50 / 450 = 0.111
P/fckbD = 548 x 103 / (12 x 230 x 450) = 0.44
M/ fck bD2 = 25 x 106 / (12x 230 x 4502) = 0.044
Using the P – M interaction curve for rectangular section
p / fck = 0.02
% p = 0.02 x 25= 0.5%
Area of steel required = 0.5 % x 230 x 450 = 517.5 mm2
But as per IS 15988:2013,
Area of steel for jacketing = (4/3) As
= (4/3) x 517.5 = 690 mm2
But minimum steel for jacketing section= 0.8% of C/S Area ofjacketed section
= 1350 mm2
Hence provide 12-12 Ø for jacketing section.
Thickness of the jacket section to be provided wills 100mm
Revised jacketed section of the column will be430mm wide x 650mm deep
Design of literal Ties
Dia of bar **=** ¼ of Ø of largest longitudinal bar
= ¼ x 16 = 4mm ….take 8mm
Spacing of bar
1. Least lateral dimension = 230mm
2. 200mm
3. 16 x Ø of smallest longitudinal reinforcement = 16x16=256mm
Provide 8mm Ø @200mm C/C

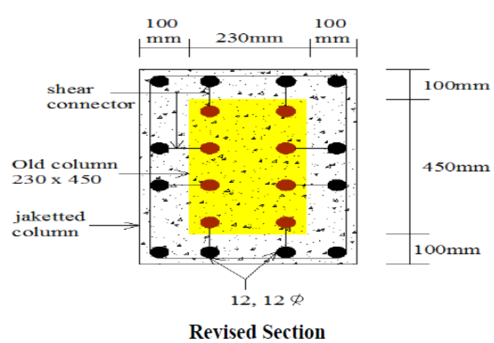


Figure 4.3: Revised column section[6]

4.4DESIGN OF RCC BEAM JACKETING AS PERIS 15988:2013

Mu = 47 kN.m, Ast provided = 2, 16 ϕ = 402.12 mm2,
fck by NDT = 12 N/mm2,fy =415 N/mm2, b = 230mm, d=360mm, D = 400mm,

RCC jacketed section
Extra Ast = 2,16ф , b = 430mm, d = 460mm,
D = 500mm

Solution:-

Due to corrosion area of reinforcement is reduces, For analysis purpose steel area is neglected

$$Xu = \frac{0.87 \text{ x Fy x Ast}}{0.36 \text{ x Fck x b}}$$

$$Xu = \frac{(0.87 \text{ x } 415 \text{ x } 0) + (0.87 \text{ x } 415 \text{ x } 402.12)}{0.36 \text{ x } 12 \text{ x } 430} = 78.15 \text{ mm}$$

M.R. = 0.138 fck bd2 = 0.138 x 12x 420x 4602
= 147.12 x106 N.mm
Mu = 0.87 fyAst (d- 0.42 Xu)
= 0.87 x 415x 402.12 (460-0.42x 78.15)
= 62.01 x106 N.mm > 47 kN ….safe

DESIGN OF SHEAR REINFORCEMENT

Step: - 1

Vu = 85kN
Ast = 2,16ф = 402.12mm2

Step: - 2

$$pt\% = \frac{100 \text{ x Ast}}{\text{b x d}} = \frac{100 \text{ x } 402.12}{430 \text{ x } 460} = 0.20$$

ζc = 0.31………….. From table
Shear capacity of section = 0.31 x bd = 0.31 x 430x 460 =61.31kN
But 61.31kN < 85 kN …………….not safe
So Design shear reinforcement required Using 2 legged 8mmф

Step: - 3

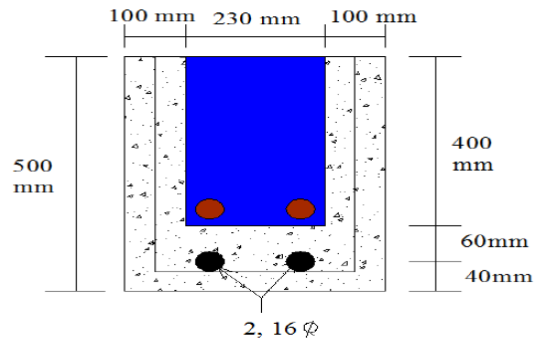
Spacing Required

$$1.\ Sv = \frac{0.87 \text{ x Fy x Asv x d}}{Vd}$$

= 707.47mm
2. = 0.75xd = 0.75x460 = 345 mm
3. = 300mm

$$4.\ Sv = \frac{0.87 \text{ x Fy x Asv}}{0.4 \text{ x b}}$$

= 211mm
Take minimum of above value
Provide 2 legged 8mm ф stirrups @200mm C/C.

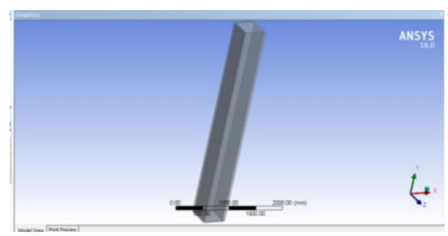


Revised Section

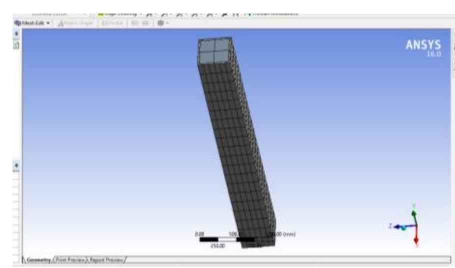
Figure 4.4: Revised beam section[6]

In such a way the analysis and design of RCC beam and column can be done effectively as per the IS15988-2013.

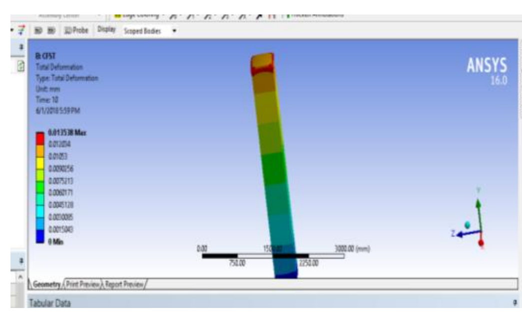
ANSYS MODELLING



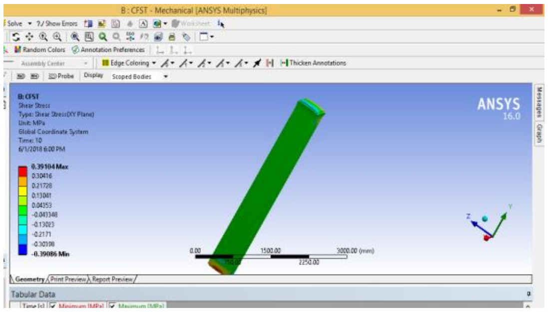
Prototype model in ansys



Meshing in ANSYS



Total deformation



Shear stress

V. RESULTS AND CONCLUSIONS

Structures strengthening are one of the numerous arising problems today in engineer's practice. Many old structural members need to be rehabilitated because of the strength degradation, due for example to a damaging earthquake, or for upgrading their performance to the design codes in force.

Different strengthening techniques can now be applied in practice as Guidelines, analysis and design is available for RCC. Due to available of repair technique like fERROCEMENT jacketing time saving repair of detoriated structure is possible by which destruction of detoriated building can be avoided in most of the cases.

The concrete is among the structural materials being widely used for this purpose. However, some inherent weaknesses of that material pushed engineers and researchers to find out ways to improve its performance for severe loading conditions. Therefore, steel fiber reinforced concrete is the alternative to the arising problem. Reinforced-concrete column strengthening by steel fiber reinforced concrete jacketing was described in this work. A simple design and analysis approach of the column's strengthening is proposed. It is based on the conventional design and analysis methods for reinforced-concrete columns and accounts for the use of steel fibers.

REFERENCES

[1] Ju´ lio, F Branco and V D Silva1, "*Structural Rehabilitation of Columns with Reinforced Concrete Jacketing*"Published online, 26 February 2003.

[2] KatsukiTakiguchi1 and Abdullah2, "*Experimental Study on Reinforced Concrete Column Strengthened With Ferrocement Jacket*", 12WCEE, 2000.

[3] P Nibasumba, X L Liu, "*Strengthening of a reinforced concrete column by steel fibre reinforced concrete jacketing: design and analysis*", 26th Conference on *Our World in Concrete & Structures*: 27 - 28 August 2001,Singapore.

[4] Shri. Pravin B. Waghmare, "*Materials And Jacketing Technique For Retrofitting Of Structures*", International Journal of Advanced Engineering Research and Studies, E-ISSN2249 – 8974-2011.

[5] Vedprakash C. Marlapalle, P. J. Salunke, N. G. Gore,"*Analysis & Design of FRP Jacketing for Buildings"*International Journal of Emerging Science and Engineering, 9, July 2014.

[6] Vedprakash C. Marlapalle, P. J. Salunke, N. G. Gore,"*Analysis & Design of R.C.C. Jacketing for Buildings",*International Journal of Recent Technology and Engineering, 3, July 2014.

[7] IS15988, *Seismic Evaluation And Strengthening Of Existing Reinforced Concrete Buildings* — Guidelines, Bureau of Indian Standards, New Delhi, 2013.