Module 10

Compression Members

Lesson 25

Design of Short Columns under Axial Load with Uniaxial Bending

Instructional Objectives:

At the end of this lesson, the student should be able to:

- state the two types of problems that can be solved using the design charts of SP-16,
- mention the three sets of design charts specifying their parameters,
- state the approximations, limitations and usefulness of the design charts of SP-16,
- mention the different steps of solving the analysis type of problems using the design charts of SP-16,
- mention the different steps of solving the design type of problems using the design charts of SP-16,
- apply the methods in solving both types of problems using the design charts of SP-16.

10.25.1 Introduction

Lesson 24 explains the procedure of preparing the design charts of short rectangular reinforced concrete columns under axial load with uniaxial bending. It is also mentioned that similar design charts can be prepared for circular and other types of cross-sections of columns by dividing the cross-section into several strips. This lesson explains the design of rectangular and circular short columns with the help of design charts.

It is known that the design of columns by direct computations involves several trials and hence, time taking. On the other hand, design charts are very useful in getting several alternative solutions quickly. Further, design charts are also used for the analysis of columns for safety etc. However, there are limitations of using the design charts, which are mentioned in this lesson. Several numerical problems are solved in this lesson for the purpose of illustration covering both analysis and design types of problems using the design charts of SP-16.

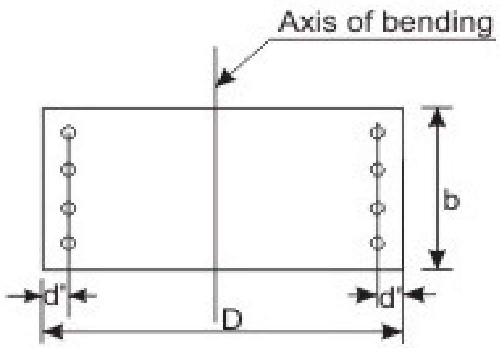

Fig.10.25.1: Rectangular column section - reinforcement distributed equally on two sides

10.25.2 Design Charts of SP-16

SP-16 has three sets of design charts prepared by following the procedure explained in Lesson 24 for rectangular and circular types of cross-sections of columns. The three sets are as follows:

(i) Charts 27 to 38 are the first set of twelve charts for rectangular columns having symmetrical longitudinal steel bars in two rows (Fig.10.25.1) for three grades of steel (Fe 250, Fe 415 and Fe 500) and each of them has four values of *d'/D* ratios (0.05, 0.10, 0.15 and 0.20).

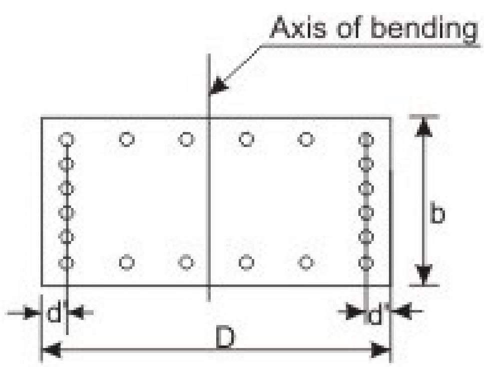

Fig.10.25.2: Rectangular column section - reinforcement distributed equally on four sides

(ii) Charts 39 to 50 are the second set of twelve charts for rectangular columns having symmetrical longitudinal steel bars (twenty numbers) distributed equally on four sides (in six rows, Fig.10.25.2) for three grades of steel (Fe 250, Fe 415 and Fe 500) and each of them has four values of *d'/D* ratios (0.05, 0.10, 0.15 and 0.20).

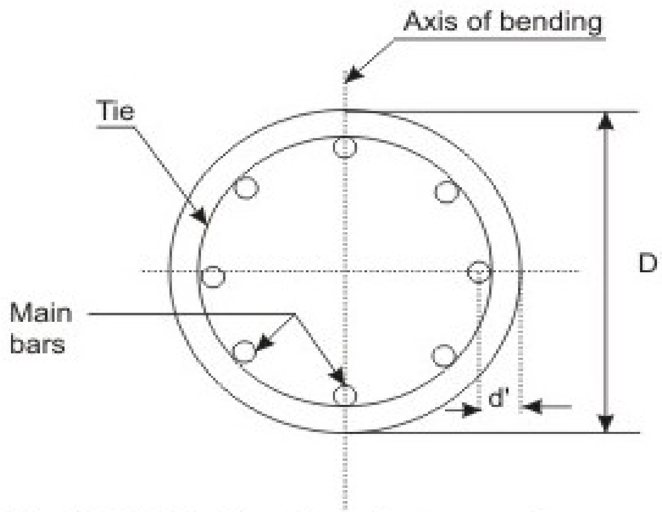

Fig.10.25.3: Circular column section - reinforcement uniformly distributed circumferencially

(iii) The third set of twelve charts, numbering from 51 to 62, are for circular columns having eight longitudinal steel bars of equal diameter and uniformly spaced circumferentially (Fig.10.25.3) for three grades of steel (Fe 250, Fe 415 and Fe 500) and each of them has four values of *d'/D* ratios (0.05, 0.10, 0.15 and 0.20).

All the thirty-six charts are prepared for M 20 grade of concrete only. This is a justified approximation as it is not worthwhile to have separate design charts for each grade of concrete.

10.25.3 Approximations and Limitations of Design Charts of SP-16

(i) Approximations

The following are the approximations of the design charts of SP-16:

(a) Grade of concrete

As mentioned in the earlier section, all the design chars of SP-16 assume the constant grade M 20 of concrete. However, each chart has fourteen plots having different values of the parameter p/f_{ck} ranging from zero to 0.26 at an interval of 0.02. The designer, thus, can make use of the actual grade of concrete by multiplying the p/f_{ck} obtained from the plot with the actual f_{ck} for the particular grade of concrete to partially compensate the approximation.

(b) The *d'/D* ratio

The three sets of charts have four fixed values of *d'/D* ratios (0.05, 0.10, 0.15 and 0.20). However, in the practical design, the *d'/D* ratio may be different from those values. In such situations intermediate values are determined by making linear interpolations.

(c) Equal distribution of twenty longitudinal steel bars on four sides of rectangular columns

In spite of the above consideration, the design charts may be used without significant error for any number of bars greater than eight provided the bars are distributed equally on four sides.

(d) Longitudinal bars in circular columns

Though the design charts are prepared considering eight bars uniformly placed circumferentially, they may generally be used for any number of bars greater than six, uniformly placed circumferentially.

(ii) Limitations

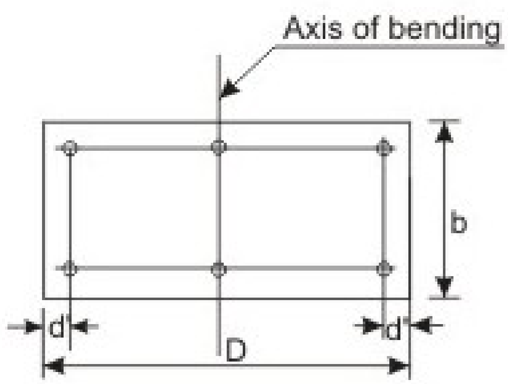

Fig.10.25.4: Six-bars arrangement

The following are the limitations of the design chars of SP-16:

(a) Longitudinal bars equally distributed on four sides of rectangular columns

Twenty bars, when equally placed on four sides, are placed in six rows avoiding any bar on the two axes. However, there will be bars on the axes for odd number of rows. A very common type is the 6-bar arrangement (Fig.10.25.4). Such arrangements, though symmetrical, are not covered in the design charts of SP-16. In such cases, the designer has to make his own assumptions judiciously in order to use the available charts of SP-16. Alternatively, he has to prepare the actual design chart depending on the bar arrangement to get accurate results.

(b) Unsymmetrical arrangement of longitudinal bars in rectangular cross-sections

It is not covered in the charts.

(c) Non-uniform placing of longitudinal bars in circular cross-sections

It is not covered in the charts.

(d) Cross-sections other than rectangular or circular like, I, T, H, X etc.

These are not covered in the charts.

The items under b, c and d, though rare, should be taken care of by preparing the respective design chars as and when needed.

(e) Concluding remarks

In spite of the above approximations and limitations, use of SP-16 has several advantages even by making some more approximations if the charts are not directly applicable. In the note of cl.39.5 of IS 456, the following is recommended, which is worth reproducing:

"The design of members subject to combined axial load and uniaxial bending will involve lengthy calculation by trial and error. In order to overcome these difficulties interaction diagrams may be used. These have been prepared and published by BIS in "SP-16 Design aids for reinforced concrete to IS 456'."

Accordingly, the use of SP-16 is explained in the following sections for the solutions of both analysis and design types of problems.

10.25.4 Use of Design Charts in the Analysis Type of Problems

In many situations, it becomes necessary to assess the safety of a column with known cross-section dimensions, and longitudinal and transverse steel reinforcing bars. The objective is to examine if the column can resist some critical values of P_u or M_u or pairs of P_u and M_u, as may be expected to be applied on the column. This is done by comparing if the given values of pair of P_u and M_u are less than the respective strength capacities pair of P_u and M_u. The word "given" shall be used in the suffix of pairs of P_u and M_u to indicate that they are the given values for which the column has to be examined. The strength capacities of the column, either P_u or M_u alone or pair of P_u and M_u, will not have any suffix. Thus, the designer shall assess

(pair of P_u and M_u)$_{given}$ < pair of P_u and M_u, as strength capacities
(10.53)

This type of problem is known as analysis type of problem. The three steps are given below while using design charts of SP-16 for solving such problems.

Step 1: Selection of the design chart

The designer has to select a particular design chart, specified by the chart number, from the known value of *d'/D* and the grade of steel for circular columns; and considering also the distribution of longitudinal steel bars equally on two or four sides for the rectangular columns.

Step 2: Selection of the particular curve

The designer shall select the particular curve out of the family of fourteen curves in the chart selected in Step 1. The selection of the curve shall be made from the value of p/f_{ck} parameter which is known.

Step 3: Assessment of the column

This can be done in any of the three methods selecting two of the three parameters as known and comparing the third parameter to satisfy Eq.10.53. The parameters are $P_u/f_{ck}\,bD$, $M_u/f_{ck}\,bD^2$ and p/f_{ck} for rectangular columns. For circular columns the breadth *b* shall be replaced by *D* (the diameter of the column).

10.25.5 Use of Design Charts in the Design Type of Problems

It is explained in sec.10.24.2 of Lesson 24 that the design of columns mainly involves with the determination of percentage of longitudinal steel *p*, either assuming or knowing the dimensions *b* and *D*, grades of concrete and steel, distribution of longitudinal bars in two or multiple rows and *d'/D* from the analysis or elsewhere. However, the designer has to confirm the assumed data or revise them, if needed. The use of design charts of SP-16 is explained below in four steps while designing columns:

Step 1: Selection of the design chart

As in step 1 of sec.10.25.4, the design chart is selected from the assumed values of the parameter as explained in step 1 of sec.10.25.4. The only difference is that, here the assumed parameter may be revised, if required.

Step 2: Determination of the percentage of longitudinal steel

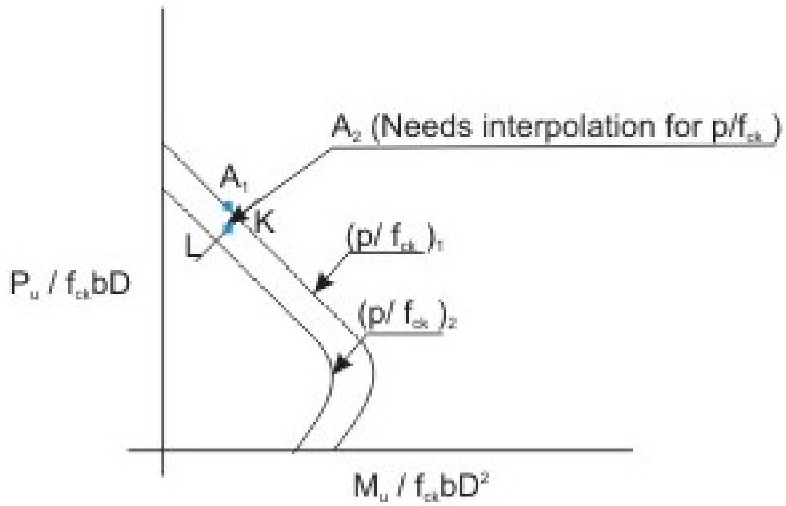

Fig.10.25.5: Determination of p/ f_{ck} by linear interpolation (not to scale)

The two parameters ($P_u/f_{ck}\,bD$) and ($M_u/f_{ck}\,bD^2$) are known and the point A is located on the design chart with these two coordinates (Fig.10.25.5). The point may be like A1, on a particular curve of specified p/f_{ck}, or like A2, in between two such curves having two values of p/f_{ck}, the difference between the two values of p/f_{ck} is 0.02. In the first case, the corresponding p/f_{ck} is obtained directly as specified on the curve. While, in the second case, liner interpolation is to be done by drawing a line KL perpendicular to the two curves and passing through the point A2.

The percentage of longitudinal steel is obtained by multiplying the p/f_{ck}, so obtained, by the actual grade of concrete (which may be different from M 20 though the chart is prepared assuming M 20 only). Thus, percentage of longitudinal steel,

$$p = (p/f_{ck})\ (\text{Actual}\ f_{ck}) \tag{10.54}$$

This percentage of longitudinal steel (obtained from Eq.10.54) is a tentative value and shall be confirmed after finalizing the assumed data, i.e., *d'/D, b, D* etc.

Step 3: Design of transverse reinforcement

This should be done before confirming *d'/D* as the diameter of the lateral tie has a role in finalizing *d'*. The design of transverse reinforcement shall be done following the procedure explained in secs.10.21.8 and 10.21.9 of Lesson 21.

Step 4: Revision of the design, if required

If the value of d'/D changes in step 3 requiring any change of other dimension etc., the repetition of steps 1 to 3 are needed. Otherwise, the design is complete.

10.25.6 Illustrative Examples

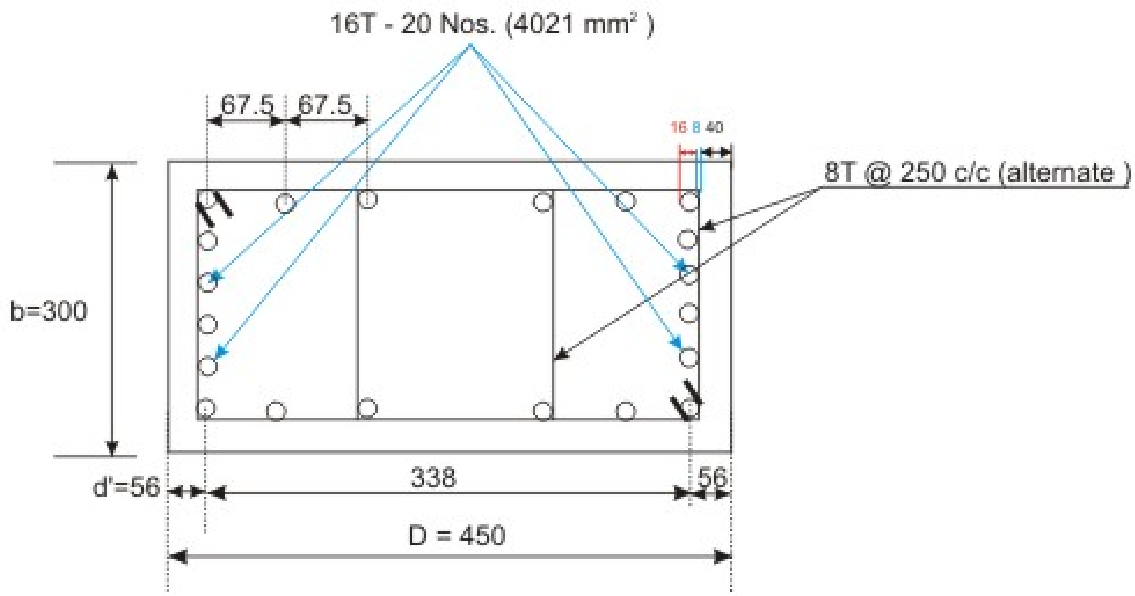

Fig. 10.25.6: Tied column of Problem 1

Problem 1:

Figure 10.25.6 shows a rectangular short reinforced concrete column using M 25 and Fe 415. Analyse the safety of the column when subjected to P_u = 1620 kN and M_u = 170 kNm.

Solution 1:

This is an analysis type of problems. The data given are: b = 300 mm, D = 450 mm, d' = 56 mm, A_{sc} = 4021 mm^2 (20 bars of 16 mm diameter), f_{ck} = 25 N/mm^2, f_y = 415 N/mm^2, P_u = 1620 kN and M_u = 170 kNm. So, we have d'/D = 56/450 = 0.1244, $P_u/f_{ck}bD$ = 0.48, $M_u/f_{ck}bD^2$ = 0.111934 and p/f_{ck} = 0.11914.

Step 1: Selection of design chart

From the given data: d'/D = 0.1244, f_y = 415 N/mm^2 and longitudinal steel bars are equally distributed on four sides, the charts selected are 44 (for d'/D =

0.1) and 45 (for d'/D = 0.15). Linear interpolation has to done with the values obtained from these two charts.

Step 2: Selection of the particular curve

From the given value of p/f_{ck} = 0.11914, the two curves having p/f_{ck} = 0.1 and 0.12 are selected from both the charts (No. 44 and 45). Here also, linear interpolation has to be done.

Step 3: Assessment of the column

In order to assess the column, we select the two given parameters p/f_{ck} and $P_u/f_{ck}bd^2$ to determine the third parameter $Mu/f_{ck}bD^2$ to compare its value with the given parameter $M_u/f_{ck}bD^2$. However, the value of $M_u/f_{ck}bD^2$ is obtained by doing linear interpolation two times: once with respect to p/f_{ck} and the second time with respect to d'/D. The results are furnished in Table 10.9 below:

Table 10.9: Values of $M_u/f_{ck}bD^2$ when $(P_u/f_{ck}bD^2)_{\text{given}}$ = 0.48 and $(p/f_{ck})_{\text{given}}$ = 0.11914; and d'/D = 0.1244

Sl. No.	p/f_{ck}	d'/D		
		0.1	0.15	0.1244
1	0.1	0.1*	0.09**	0.09512***
2	0.12	0.12*	0.107**	0.113656***
3	0.11914	0.1194***	0.10649***	0.1130941***

Note: * Values obtained from chart 44
** Values obtained from chart 45
*** Linearly interpolated values

Thus, the moment capacity of the column is obtained from the final value of $M_u/f_{ck}bD^2$ = 0.1130941 as

$$M_u = (0.1130941)(25)(300)(450)(450) \text{ Nmm} = 171.762 \text{ kNm},$$

which is higher than the given M_u = 170 kNm. Hence, the column can be subjected to the pair of given P_u and M_u as 1620 kN and 170 kNm, respectively.

Problem 2:

Design a short spiral column subjected to P_u = 2100 kN and M_u = 187.5 kNm using M 25 and Fe 415. The preliminary diameter of the column may be taken as 500 mm.

Solution 2:

Step 1: Selection of design chart

With the given f_y = 415 N/mm^2 and assuming d'/D = 0.1, the chart selected for this problem is Chart 56.

Step 2: Determination of the percentage of longitudinal steel

With the given f_{ck} = 25 N/mm^2 and assuming the given D = 500 mm, we have:

$P_u/f_{ck}D^2$ = 2100000/25(500)(500) = 0.336, and

$M_u/f_{ck}D^3$ = 187.5(10^6)/25(500)(500)(500) = 0.06

The particular point A (Fig.10.25.5) having coordinates of $P_u/f_{ck}D^2$ = 0.336 and $M_u/f_{ck}D^3$ = 0.06 in Chart 56 gives: p/f_{ck} = 0.08. Hence, p = 0.08(25) = 2 per cent (see Eq.10.54).

A_{sc} = 0.02(π)(500)(500)/4 = 3928.57 mm^2

Provide 8-25 mm diameter bars to have A_{sc} actually provided = 3927 mm^2. Marginally less amount of steel than required will be checked considering the enhancement of strength for spiral columns as stipulated in cl.39.4 of IS 456.

Step 3: Design of transverse reinforcement

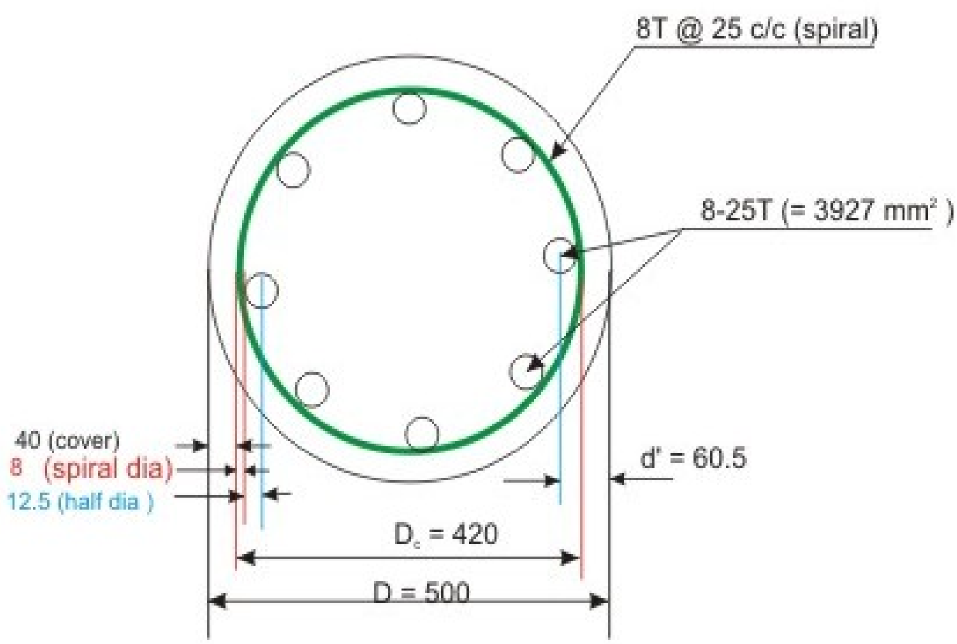

Fig. 10.25.7: Spiral column of Problem 2

The diameter of the helical reinforcement is taken as 8 mm (> 25 mm/4). The pitch p of the spiral is determined from Eq.10.11 of Lesson 22, which satisfies the stipulation in cl.39.4.1 of IS 456. From Eq.10.11, we have the pitch of the spiral p as:

$$p \leq 11.1(D_c - \phi_{sp})\, a_{sp}\, f_y/(D^2 - D_c^2)\, f_{ck} \quad .... \quad (10.11)$$

where, D_c = 500 – 40 – 40 = 420 mm, D = 500 mm, f_{ck} = 25 N/mm^2, f_y = 415 N/mm^2, ϕ_{sp} = 8 mm and a_{sp} = 50 mm^2.

Using the above values in Eq.10.11, we have $p \leq$ 25.716 mm. As per cl.26.5.3.2d1, regarding the pitch of spiral: $p \not> 420/6$ (= 70 mm), $p \not< 25$ mm and $p \not< 24$ mm. So, pitch of the spiral = 25 mm is o.k. Figure 10.25.7 presents the cross-section with reinforcing bars of the column.

Step 4: Revision of the design, if required

Providing 25 mm diameter longitudinal steel bars and 8 mm diameter spirals, we have d' = 40 + 8 + 12.5 = 60.5 mm. This gives d'/D = 60.5/500 = 0.121. In step 1, d'/D is assumed as 0.1. So, the revision of the design is needed.

However, as mentioned in step 2, the area of steel required is not provided and this may be offset considering the enhanced strength of the spiral column, as stipulated in cl.39.4 of IS 456.

We, therefore, assess the strength of the designed column, when d'/D = 0.121 and A_{sc} = 3927 mm^2, if it can be subjected to P_u = 2100 kN and M_u = 187.5 kNm.

For the purpose of assessment, we determine the capacity P_u of the column when M_u = 187.5 kNm. Further, the revised d'/D = 0.121 needs to interpolate the values from Charts 56 (for d'/D = 0.1) and 57 (for d'/D = 0.15). The value of p/f_{ck} = 0.08 and $M_u/f_{ck}bD^3$ = 0.06. Table 10.10 presents the results.

Table 10.10: Value of $P_u/f_{ck}bD^2$ when $M_u/f_{ck}D^3$ = 0.06 and p/f_{ck} = 0.08

Sl.No.	d'/D	$P_u/f_{ck}D^2$
1	0.1	0.336 (from Chart 56)
2	0.15	0.30 (from Chart 57)
3	0.121	0.32088 (Interpolated value)

From Table 10.10, thus, we get,

$P_u/f_{ck}D^2$ = 0.32088, which gives P_u = (0.32088)(25)(500)(500) = 2005.5 kN.

Considering the enhanced strength as 1.05 times as per cl.39.4 of IS 456, the actual capacity of this column is (1.05)(2005.5) = 2105 kN > 2100 kN.

Thus, the design is safe to carry P_u = 2100 kN and M_u = 187.5 kNm.

10.25.7 Practice Questions and Problems with Answers

Q.1: Name the two types of problems that can be solved using the design charts of SP-16.

A.1: See sec. 10.25.1.

Q.2: Mention the three different sets of design charts available in SP-16 mentioning the number of charts and the parameters for their identification.

A.2: See sec. 10.25.2.

Q.3: State the approximations, limitations and usefulness of the design charts of SP-16 in solving the analysis and design type of problems of short columns.

A.3: See sec. 10.25.3.

Q.4:

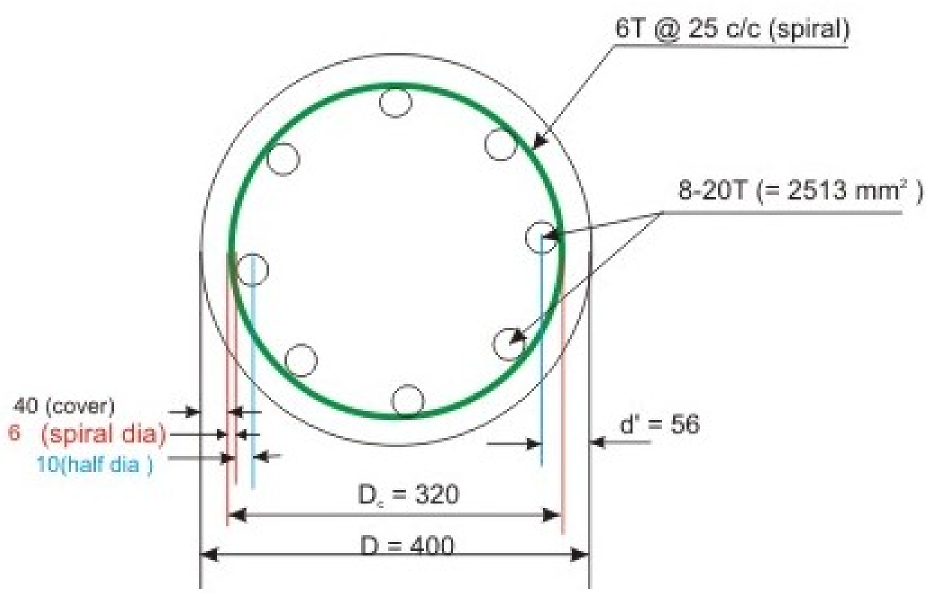

Fig. 10.25.8: Spiral column of Q. 4

Assess the safety of the spiral column shown in Fig.10.25.8 using M 20 and Fe 415 when subjected to P_u = 1200 kN and M_u = 64 kNm, considering the enhanced strength of the spiral column.

A.4: In this problem, the given data are: D = 400 mm, d' = 40 + 6 + 10 = 56 mm, A_{sc} = 2513 mm^2 (8-20 mm diameter bars), f_{ck} = 20 N/mm^2, f_y = 415 N/mm^2, P_u = 1200 kN and M_u = 64 kNm.

Step 1: Selection of the design charts

With f_y = 415 N/mm^2 and d'/D = 56/400 = 0.14, we select two charts nos. 56 (for d'/D = 0.1) and 57 (for d'/D = 0.15). We have to interpolate the values obtained from these two charts.

Step 2: Selection of the particular curve

From the given data we have p/f_{ck} = 0.0999488 $\cong$ 0.1. So, we select the curve for p/f_{ck} = 0.1 in the two charts (Nos. 56 and 57).

Step 3: Assessment of the column

For the purpose of assessment, we select the two parameters p/f_{ck} and $M_u/f_{ck}D^3$ and determine the values of $P_u/f_{ck}D^2$ from the two charts for interpolation. The results are presented in Table 10.11 below.

Table 10.11: Values of $p/f_{ck}D^2$ and $M_u/f_{ck}D^3$ and p/f_{ck} = 0.1

Sl.No.	d'/D	$P_u/f_{ck}D^2$
1	0.1	0.444 (from Chart 56)
2	0.15	0.422 (from Chart 57)
3	0.14	0.4264 (Interpolated value)

From Table 10.11, thus, we get $P_u/f_{ck}D^2$ = 0.4264, which gives P_u = 1364.48 kN.

It may be noted that for more accuracy another set of values of d'/D = 0.08 is required. The interpolated value, thus obtained, shall be strictly applicable when p/f_{ck} = 0.0999488. However, for all practical designs, such accuracy is not required.

Further, as per cl.39.4 of IS 456, the enhanced capacity of the spiral column = 1.05(1364.48) = 1432.704 kN, which is more than 1200 kN. It is also seen that the column is safe even without considering the enhanced capacity as the P_u = 1364.48 kN > 1200 kN.

Q.5:

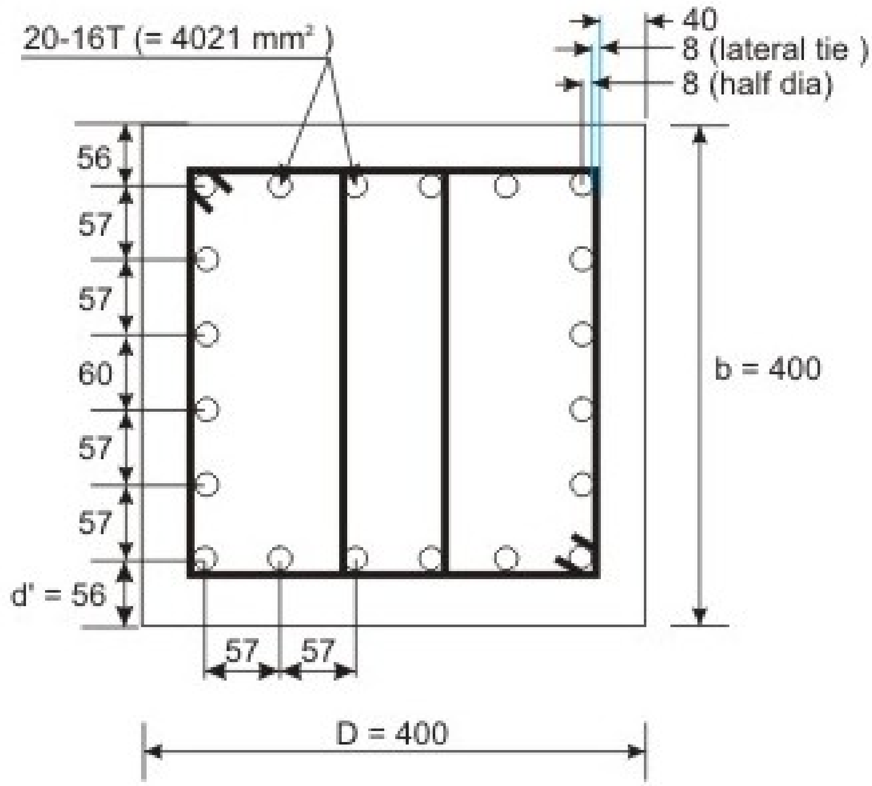

Fig .10.25.9: Square column of Q. 5

Design a short square tied column to carry P_u = 2240 kN and M_u = 112 kNm using M 25 and Fe 415, and assuming the dimension b = D = 400 mm, as shown in Fig.10.25.9.

A.5: The data given are: b = D = 400 mm, P_u = 2240 kN, M_u = 112 kNm, f_{ck} = 25 N/mm^2 and f_y = 415 N/mm^2.

Step 1: Selection of the design chart

With the given data of f_y = 415 N/mm^2 and assuming d'/D = 0.15, we have to refer to Chart 45.

Step 2: Determination of percentage of longitudinal steel

Using the values of f_{ck} = 25 N/mm^2 and assuming b = D = 400 mm as given, we have $P_u/f_{ck}D^2$ = 0.56 and $M_u/f_{ck}D^3$ = 0.07.

From Chart 45, we get p/f_{ck} = 0.1, giving p = 2.5 per cent. Accordingly,

A_{sc} = 2.5(400)(400)/100 = 4000 mm^2. Provide 20 bars of 16 mm diameter ($A_{sc(\text{provide})}$ = 4021 mm^2).

Step 3: Design of lateral tie

The arrangement of lateral tie shall be like Fig.18 of IS 456 as the longitudinal bars are not spaced more than 75 mm on either side (cl.26.5.3.2b1 of IS 456). The pitch of the lateral tie of diameter 8 mm is kept at 250 mm c/c satisfying the stipulation in cl.26.5.3.2c1 of IS 456. Figure 10.25.9 presents the cross-section with reinforcing bars of the column.

Step 4: Revision of the design, if required

The value of *d'* is now 56 mm which gives *d'/D* = 0.14. Accordingly, the assumed value of *d'/D* in step 1 as 0.15 is not valid. So, we have to check the capacity of the column interpolating the values when *d'/D* = 0.1 and 0.15 from Charts 44 and 45, respectively. Further, the longitudinal steel provided gives p/f_{ck} = 0.100525, which also is different from 0.1 as obtained in step 2 of this problem. Though the difference is marginal, both the interpolations are done for the academic interest and results are presented in Table 10.12 below. In assessing the capacity of this column, we keep p/f_{ck} = 0.100125 and $P_u/f_{ck}D^2$ = 0.56 as constants and determine the value of $M_u/f_{ck}D^3$ by two linear interpolations.

Table 10.12: Values of $M_u/f_{ck}D^3$ when $P_u/f_{ck}bD^2$ = 0.56 and p/f_{ck} = 0.10025

Sl. No.	p/f_{ck}	*d'/D*		
		0.1	0.15	0.14
1	0.1	0.1*	0.07**	0.072***
2	0.12	0.08*	0.09**	0.092***
3	0.100525	0.080525***	0.070525***	0.072525***

Note: * Values obtained from Chart 44
** Values obtained from Chart 45
*** Linearly interpolated values

So, the capacity of the column M_u = (0.072525)(25)(400)(400)(400) Nmm = 116 kNm > 112 kNm.

Hence, the design of the column is o.k.

10.25.8 References

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15. Indian Standard Plain and Reinforced Concrete – Code of Practice (4th Revision), IS 456: 2000, BIS, New Delhi.
16. Design Aids for Reinforced Concrete to IS: 456 – 1978, BIS, New Delhi.

10.25.9 Test 25 with Solutions

Maximum Marks = 50, Maximum Time = 30 minutes

Answer all questions.

TQ.1: Mention the three different sets of design charts available in SP-16 mentioning the number of charts and the parameters for their identification. (10 marks)

A.TQ.1: See sec. 10.25.2.

TQ.2: State the approximations, limitations and usefulness of the design charts of SP-16 in solving the analysis and design type of problems of short columns. (10 marks)

A.TQ.2: See sec. 10.25.3.

TQ.3:

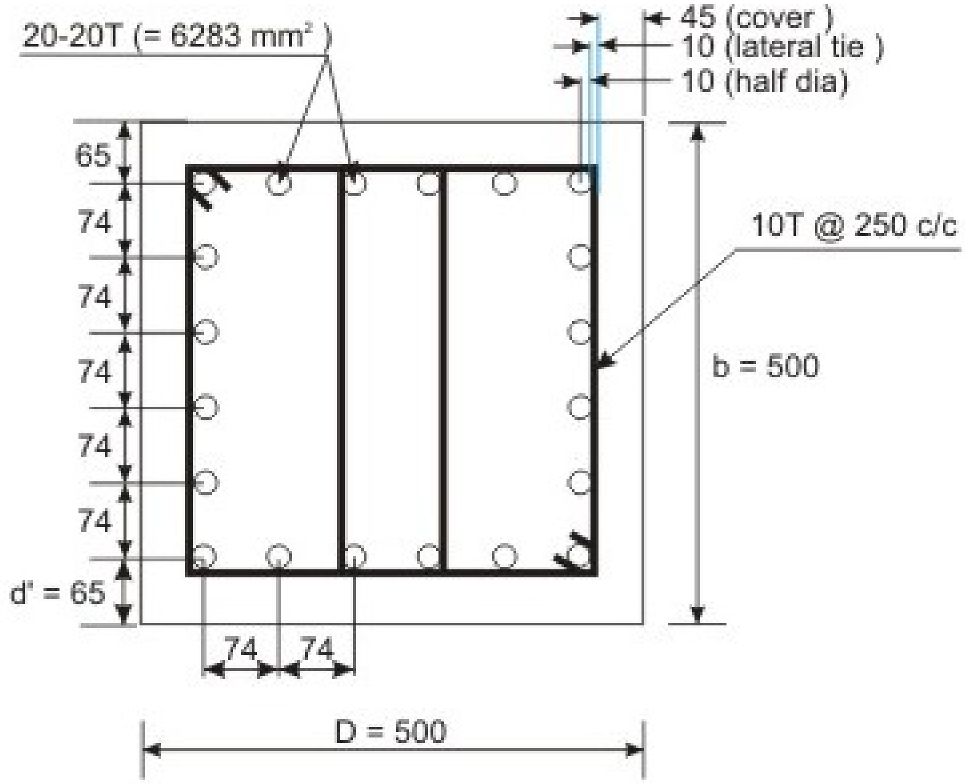

Fig .10.25.10: Square column of TQ. 3

Check the short square column of Fig.10.25.10 to carry P_u = 3250 kN and M_u = 250 kNm using M 25 and Fe 415. (30 marks)

A.TQ.3: Given data are: b = D = = 500 mm, A_{sc} = 6283 mm^2 (20 bars of 20 mm diameter), f_{ck} = 25 N/mm^2, f_y = 415 N/mm^2, P_u = 3250 kN and M_u = 250 kNm.

Step 1: Selection of design chart

From Fig.10.25.10, we get d' = 65 mm giving d'/D = 0.13, and given f_y = 415 N/mm^2, we select Charts 44 (for d'/D = 0.1) and 45 (for d'/D = 0.15). We have to interpolate the values to get the result when d'/D = 0.13.

Step 2: Selection of the particular curve

With p = 628300/(500)(500) = 2.5132 per cent, we get p/f_{ck} = 0.100528 $\cong$ 0.1. Accordingly, the curve for p/f_{ck} = 0.1 is to be used in Charts 44 and 45.

Step 3: Assessment of the column

For the assessment, we keep $P_u/f_{ck}D^2$ = 3250/25(500)(500) = 0.52 and p/f_{ck} = 0.1 as constants to determine $M_u/f_{ck}D^3$ from two charts. The results are given in Table 10.13 below.

Table 10.13: Values of $M_u/f_{ck}D^3$ when $P_u/f_{ck}D^2$ = 0.52 and p/f_{ck} = 0.1

Sl.No.	d'/D	$M_u/f_{ck}D^3$
1	0.1	0.09 (from Chart 44)
2	0.15	0.08 (from Chart 45)
3	0.13	0.084 (Interpolated value)

So, we get $M_u/f_{ck}D^3$ = 0.084, giving M_u = (0.084)(25)(500)(500)(500) = 262.5 kNm > 250 kNm.

Hence, the column is safe to carry P_u = 3250 kN and M_u = 250 kNm.

10.25.10 Summary of this Lesson

This lesson explains the approximations, limitations and usefulness of the three sets of design charts available in SP-16 for the purpose of solving analysis and design types of reinforced concrete columns. The use of design charts has been illustrated in several steps for the solution of both analysis and design types of problems.

Several numerical problems in illustrative examples, practice problem and test will help in understanding the use of design charts to solve the two types of problems.