SAMPLE QUANTITIES REPORT

RCC structure quantities

Example house: G+1, 1,000 sq ft per floor

PREPARED FOR	LOCATION	REPORT ID	DATE
Example house (sample)	Lucknow, Uttar Pradesh	NS-SP-SAMPLE	29 October 2026

This is a sample report
It is a real report from the same calculations a paid report uses, made for an example house (G+1, 1,000 sq ft on each floor, Lucknow). It is not your project and nothing in it applies to your plot. Your own report uses your plot, floors and city, so its figures will differ.

Your building

FLOORS	BUILT-UP AREA	EARTHQUAKE ZONE
G+1	**2,000 sq ft** 185.8 m²	**Zone III**

GROUND	CONCRETE	STEEL AND WALLS
ordinary firm soil	**M20 above, M25 below**	**Fe500D · Burnt clay brick walls**

Zone III for Lucknow (IS 1893:2002 Annex E). IS 1893:2016 is the edition in force: confirm with a local structural engineer.

What to order

Totals for the whole structure. The line under each figure is the range the real number is likely to fall in.

CONCRETE	STEEL TO BUY	CEMENT	SHUTTERING
58.5 m³	**5,418** kg	**493** bags	**5,454** sq ft
54 to 82 m³	4,876 to 8,668 kg	454 to 691 bags	4,636 to 6,818 sq ft

How to use this report
This is a code-based planning estimate, not a structural design for your drawings. It designs a regular frame to the Indian Standards and counts the extras. Use it to check a contractor's quantities for gross errors and to order the first lots. A real building is more likely to use more than this than less, so for a budget plan on the upper half of each range. Get the final bar bending schedule from the structural engineer who signs your drawings.

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Buy list

MATERIAL	QUANTITY	UNIT	HOW IT WAS WORKED OUT
Cement (50 kg bags)	493	bags	Per cubic metre of each mix, plus 3% site wastage
Sand	945	cft	26.7 m³
Coarse aggregate	1,852	cft	52.4 m³
Reinforcement steel Fe500D	5,418	kg	Bar weight 5,160 kg + 5% cutting waste (CPWD DAR 5.22.1)
Binding wire	46.4	kg	9 kg per tonne of steel
Shuttering (contact area)	5,454	sq ft	507 m² of formwork face
Excavation	4,404	cft	124.7 m³ for the foundation pits

Concrete, steel and shuttering by part

PART	PIECES	CONCRETE m³	STEEL kg	SHUTTERING m²
Footings (or raft)	12	4.72	139	8.8
Plinth beams	17	4.77	419	55.5
Columns	24	8.64	1,345	109.4
Floor beams	34	5.78	1,230	78.4
Slabs	12	26.83	1,497	149.7
Staircase	2	3.03	113	29.0
Lintels, sunshades, parapet band, stair head-room	62	4.73	416	75.8
Reinforced concrete total		**58.51**	**5,160**	**506.7**

Steel here is the bar weight before the 5% cutting waste. Lean concrete under the footings (M7.5) is 2.48 m³ and is not part of the total above.

Steel by bar diameter

DIAMETER	WEIGHT TO BUY kg	12 m BARS
6 mm	102	coil
8 mm	2,919	617
10 mm	369	50
12 mm	1,467	138
16 mm	241	13
20 mm	320	11
All diameters	**5,418**	**829**

Weights include the 5% cutting waste. The bar count rounds each diameter up to whole 12 m lengths (weight per metre = d²/162.2, IS 1786). 6 mm bar is bought as a coil and cut and bent on site, so it has no bar count.

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Mixes

WHERE	GRADE	CEMENT kg/m³	SAND m³/m³	AGGREGATE m³/m³
above ground	M20	400	0.43	0.85
foundations and below ground	M25	411	0.42	0.76
lean concrete under footings	M7.5	170	0.47	0.89

M20 above ground: CPWD DAR 2014 item 4.1.2, nominal mix 1:1.5:3

M25 foundations and below ground: IS 10262:2009 design mix, w/c 0.48, water 197 L, 20 mm aggregate

M7.5 lean concrete under footings: CPWD DAR 2014 item 4.1.8, nominal mix 1:4:8

Columns

STOREY	TYPE	PIECES	SIZE mm	MAIN BARS	STEEL %	TIES
Ground floor	corner	4	300 x 300	4-16	0.89	8 @ 75/150
Ground floor	edge	2	300 x 350	4-20	1.20	8 @ 75/150
Ground floor	edge	4	350 x 300	8-12	0.86	8 @ 75/150
Ground floor	interior	2	300 x 350	4-20	1.20	8 @ 75/150
First floor	corner	4	300 x 300	8-12	1.01	8 @ 75/150
First floor	edge	2	300 x 350	8-16	1.53	8 @ 75/150
First floor	edge	4	350 x 300	8-12	0.86	8 @ 75/150
First floor	interior	2	300 x 350	4-20	1.20	8 @ 75/150

Beams

SLAB LEVEL	BEAM	PIECES	SIZE mm	BARS
First floor	edge beam	4	230 x 350	bottom 3-12, top 2-12 + 3-12; stirrups 8 @ 100/150
First floor	edge beam	2	230 x 375	bottom 2-12, top 2-12 + 3-12; stirrups 8 @ 100/150
First floor	inner beam	2	230 x 350	bottom 3-12, top 2-12 + 2-12; stirrups 8 @ 100/150
First floor	inner beam	1	230 x 350	bottom 3-12, top 2-12 + 3-12; stirrups 8 @ 100/150
First floor	edge beam	4	230 x 400	bottom 4-12, top 2-12 + 4-12; stirrups 8 @ 100/175
First floor	inner beam	4	230 x 400	bottom 4-12, top 2-12 + 4-12; stirrups 8 @ 100/175
Roof	edge beam	6	230 x 300	bottom 2-12, top 2-12 + 1-12; stirrups 8 @ 100/125
Roof	inner beam	3	230 x 300	bottom 3-12, top 2-12 + 2-12; stirrups 8 @ 100/125
Roof	edge beam	4	230 x 350	bottom 3-12, top 2-12 + 2-12; stirrups 8 @ 100/150
Roof	inner beam	4	230 x 375	bottom 4-12, top 2-12 + 3-12; stirrups 8 @ 100/150

Bars read as number-diameter: 8-16 means eight 16 mm bars. In beams, the top bars are two continuous bars plus the extra bars after the plus sign, which sit over the supports. Every size is the smallest the tool's IS 456 and IS 13920 checks accept for your zone, except where the report says a limit is reached; your engineer may round up.

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Smaller items, counted

ITEM	COUNT	CONCRETE m³	STEEL kg	BASIS
Lintels over doors and windows	37	1.61	183	150 mm deep, 200 mm bearing each side; 1.2 m windows every 3.6 m of outer wall, one door per 13 m2. Site practice: ASSUMPTION.
Sunshades (chajjas)	23	1.16	95	450 mm projection, 75 mm thick, 8 mm @ 150 main and 6 mm @ 200 distribution over every window and the main door. Site practice: ASSUMPTION.
Terrace parapet coping band	1	0.34	43	115 x 75 mm band with 2-8 and 6 mm @ 250 along the roof edge. Site practice: ASSUMPTION.
Stair head-room (mumty) roof	1	1.63	96	100 mm roof slab with 8 mm @ 150 each way and a 230 x 230 mm ring beam (4-10, 6 mm @ 150) over the stair well. Site practice: ASSUMPTION.

The frame we designed

FOOTPRINT
11.0 x 8.5 m

COLUMN GRID
3 x 2 bays
Spans about 3.66 x 4.23 m

STOREY HEIGHT
3.0 m
Plinth 0.45 m above ground

FOUNDING DEPTH
1.5 m
Below ground level

STEEL PER m²
27.8 kg
Of built-up floor area

CONCRETE PER m²
0.315 m³
Of built-up floor area

WIND SPEED USED
47 m/s
Earthquake is the larger force

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Checks against the Indian Standards

These are the checks the tool makes. A status of PASS for the steel grade or the concrete grade follows from the tool's own choices. Where a line says a limit is reached, the section shown does not pass it. Appendix A lists what the tool does not check.

PASS IS 456:2000 cl 6.1, Table 5
Concrete grade against exposure
M20 above ground and M25 below ground meet the minimum grade, cement content and water-cement ratio for mild exposure.

PASS IS 13920:1993 cl 5.3 (Amendment No. 2); IS 1786:2008
Reinforcement grade
Zone III calls for ductile steel: this report uses Fe500D throughout.

NOTE IS 13920:1993 cl 6 and 7
Ductile detailing
Zone III: closer stirrups at beam and column ends and 135-degree hooks are in the bar counts. The strong-column weak-beam check uses the tool's own factor of 1.1, where IS 13920:2016 asks for 1.4, and the confining steel of the columns is not checked, so the ties on signed drawings are likely to be heavier. Your contractor must follow the engineer's drawings on site.

PASS IS 1904:1986; IS 456 cl 34
Foundation
Isolated footings on the bearing capacity assumed for your site type. Replace the assumed value with a soil test result.

NOTE IS 456:2000 cl 26.4, Table 16

Nominal cover

Footing 50 mm, column 40 mm, beam 25 mm, slab 20 mm, the same for every site. For moderate or severe exposure IS 456 Table 16 asks for more cover than the beam and slab figures here, which the engineer sets on the drawings. Cover blocks must be placed on site.

PASS IS 875 (Part 3):1987 cl 5; IS 1893 (Part 1) cl 6.2

Wind load check

Basic wind speed 47 m/s for Lucknow. The wind force is compared with the earthquake force storey by storey and the larger of the two is designed for; they are never added. In both directions the earthquake force is the larger one.

How far off can this be

- Concrete: from 8% below to 40% above the figure shown.
- Steel: from 10% below to 60% above.
- Cement: from 8% below to 40% above.
- Shuttering: from 15% below to 25% above.

Against buildings that were actually built

The figures in this report are the steel and concrete a code-based design of this regular frame needs, at the section sizes shown. Built houses usually use more, because site practice adds margin that no code asks for. For orientation, here is what a published study of real buildings of up to four storeys found.

	THIS REPORT	REAL BUILDINGS, LOW TO HIGH	FOR YOUR FLOOR AREA
Steel per m² of floor (bar weight)	27.8 kg	31 to 62 kg	5,760 to 11,520 kg
Concrete per m² of floor	0.31 m³	0.36 to 0.44 m³	66.9 to 81.8 m³

If your contractor's quantities fall between this report and the real-building range, that is common and worth a conversation, not an accusation. If they are above the range, ask for the bar bending schedule. Source: GKSPL, Building the Baseline: Embodied Carbon in India's Urban Housing, v1, March 2026 (26 residential buildings, from Bills of Quantities), as reported by Conserve Consultants, 29 April 2026. The study does not publish how many buildings fell in each class, so treat the range as orientation, not as a prediction for your house.

Assumptions

- Layout: regular grid of 3 x 2 bays of about 3.66 x 4.23 m, storey height 3 m, plinth 0.45 m. Your own drawing will differ.
- Seismic zone III. Zone III for Lucknow (IS 1893:2002 Annex E). IS 1893:2016 is the edition in force: confirm with a local structural engineer.
- Zone III and above: special moment-resisting frame, ductile detailing to IS 13920:1993 (closer stirrups at the ends and tie spacing to cl. 7.4.6, a strong-column weak-beam check at the tool's own factor of 1.1; the confining-steel area of cl. 7.4.8 is not checked).
- Concrete: M20 above ground and M25 for foundations, chosen from the exposure condition (IS 456 Table 5). Steel: Fe500D.
- Foundation: isolated footings on ordinary firm soil, safe bearing capacity 150 kN/m2 assumed, founding depth 1.5 m. Replace with a soil test.
- Loads: floor finish 1.5 kN/m2, imposed 2.0 kN/m2 on floors and 1.5 kN/m2 on the roof (IS 875), brick walls 230 mm outside, 115 mm brick partitions on half the inner beams, 15 % off for openings.
- Slab 150 mm thick (span/depth, IS 456 cl 23.2); beams 230 mm wide with depth from bending, shear and deflection; columns sized by the biaxial check of IS 456 cl 39.6.
- Reinforcement is bought in 12 m bars (6 mm comes as a coil, cut and bent on site) with 5 % wastage (CPWD DAR 5.22.1). Binding wire is 9 kg per tonne.
- Lintels, sunshades, the terrace parapet band and the stair head-room roof are counted from the plan perimeter and floor area (37 lintels over doors and windows, 23 sunshades (chajjas), 1 terrace parapet coping band, 1 stair head-room (mumty) roof); their sizes are site practice, not code values.

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- Cement, sand and aggregate: CPWD Delhi Analysis of Rates 2014 for M20 and below, IS 10262 mix design above that, plus 3 % site wastage.
- Wind to IS 875 (Part 3): basic speed 47 m/s for Lucknow, open terrain, roof-level pressure 1.33 kN/m2. Base shear 61 / 79 kN (along x / y) against 91 / 91 kN for the earthquake: the earthquake governs in both directions. The larger force sets the design, storey by storey; wind and earthquake are never added (IS 1893 cl 6.2).
- Soil-structure interaction and torsion are not analysed; the earthquake forces are IS 1893 equivalent static forces shared equally between frames. Wind pressures use the 1987 basis with no directionality factor and no hill or shielding effect. The wind speed for a town comes from a published city table: the engineer should confirm it against the wind map of IS 875 (Part 3).

Not counted in this report

- Brick or block masonry, plaster, flooring, doors, windows, painting, waterproofing
- Lift shaft, basement, water tank, sump, septic tank, compound wall, boundary gate
- Balconies, porticos, canopies and other cantilevers beyond the main grid
- Backfilling, plinth filling, anti-termite treatment, curing water, scaffolding hire
- Plumbing, electrical and finishing works

Standards and sources used

- IS 456:2000 Plain and reinforced concrete: limit state design, cover, detailing, slabs, beams, columns and footings.
- IS 875 Parts 1, 2 and 3: dead, imposed and wind loads. IS 1893 Part 1 (2002 edition): earthquake forces, zone factors and the open-storey rule. IS 13920: ductile detailing (the tool works to the 1993 edition; the 2016 edition is now in force).
- IS 1786:2008: Fe500D bars and mass per metre. IS 10262: concrete mix proportioning. IS 1904: foundations on soil.
- CPWD Delhi Analysis of Rates 2014: nominal-mix cement, sand and aggregate for M20 and below, and the 5% steel cutting waste.

NirmanShastra · India's IS-code construction quantities platform. This report is for estimation and planning only. It is not a substitute for drawings and calculations signed by a licensed structural engineer, and it does not replace a soil test. The bearing capacity, floor loads and site-practice sizes are stated assumptions; change them and the quantities change.

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APPENDIX A

Calculation sheet

StructurePro: how every figure in this report was worked out

What this sheet is

This sheet shows how every quantity in the StructurePro report was worked out. The tool designs a regular frame for your building by hand methods to the Indian Standards, records every bar, and carries the concrete, the steel and the shuttering to the buy list. The sheet is for the structural engineer, the bank valuer or the contractor who wants to check the quantities. It is a planning estimate and not a structural design for your drawings.

How to read it

Each row is one step. STEP says what is being found. FORMULA gives it in symbols. WORKING puts the numbers in. RESULT is the answer with its unit. SOURCE names the clause or table the step rests on. The columns take turns being a lighter and a darker cream, so each figure sits under its own heading. Amber rows are inputs: a figure you gave, or a value read from a code table. Green rows are figures that appear in the report. Every sum was carried out at full precision and is shown rounded, so re-keying the rounded numbers by hand may differ in the last digit.

Method in brief

1. The tool reads your answers (floors and their areas, the place, the ground, the walls, an open parking level, balconies) and derives the earthquake zone, the wind speed, the concrete grade and the cover from them (Sections 1 and 2).
2. It lays a regular grid of bays of about 3.75 m (never over 5 m) over the largest floor, scales every floor to the area you gave, and fixes the slab thickness from span and depth ratios (Section 3).
3. It adds up the dead and imposed loads on the slabs, walls and beams, and replaces the slab load on each beam by an equal uniform load (Section 4).
4. It finds the earthquake force by the equivalent static method of IS 1893 and the wind force by IS 875 (Part 3), takes the larger of the two storey by storey, and shares it between the frames and columns by the portal method (Section 5).
5. It designs every beam: a depth is searched from span ÷ 13 upward, the moments come from IS 456 Table 12 and the lateral force, and the bars and stirrups follow IS 456 and, from Zone III upward, the ductile rules of IS 13920 (Section 6).
6. It designs every column for seven load cases (and, in Zone III and above, a strong-column weak-beam check that is the model's own) by strain compatibility, and sets the ties (Section 7). The beams and the seismic weights depend on each other, so the whole analysis is run twice and the second run uses the member sizes of the first.
7. It sizes the foundation: an isolated footing under every column from its load and the bearing capacity assumed for the ground, or a raft where the ground or the loads ask for one, with the lean concrete under the footings and the plinth beams (Section 8).
8. It designs the floor slabs panel by panel with the coefficients of IS 456, the staircase and the balconies, and counts the lintels, sunshades, terrace parapet band and stair head-room roof from the plan (Sections 9 and 10).
9. Every bar of every member is recorded with its diameter, cut length and number. The bars are weighed again and added by member and by diameter, and the steel to buy adds the cutting waste (Section 11).
10. It counts the concrete and the shuttering of the columns and beams from the sizes found and sets them beside those of the other members (Section 12).
11. It takes the cement, sand and aggregate in a cubic metre of each grade of concrete, multiplies by the concrete of each mix, adds the site wastage and turns the result into the buy list (Section 13).

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12. The ranges, the comparison with built houses, the checks, the warnings and the assumptions of the report are placed in Section 14. The last table sets every figure of the report beside the same figure worked here. The sheet is printed only if every figure agrees. That shows the sheet and the report agree with each other, because the sums were done twice. It is not a check against the standards or against what a site will use.

Read this before relying on the sheet

- This is a planning model for quantities, not a structural design. The frame is analysed by hand methods (coefficients for the beams, the portal method for the lateral force), not by a computer frame analysis, and no drawing, joint detail or bar bending schedule is produced. A licensed structural engineer must design and sign the real building.
- Beams: the moments are the coefficients of IS 456 Table 12 for equal continuous spans. The outer-support coefficient of 1/16 and the 10 % rise in the support shear are the model's own planning values, and the beams are designed with an estimated column size. Compression steel is not designed (the tension steel is raised by 15 % when a section is over its limit), deflection is checked by span and depth ratios with an assumed modification factor, and torsion, crack width and anchorage in the joints are not checked.
- Columns: each column is checked for axial load with biaxial bending on the load cases of Section 7 and the minimum eccentricity. Slenderness, the change in axial load from the overturning of the building, column shear and joint shear are not designed. The ties follow the spacing rules, and in Zone III and above the tie size is 8 mm (10 mm with 25 mm bars). The confining-steel area of IS 13920 cl. 7.4.8 is not checked by the model. Section 7 works it for every column row beside the model's ties, under two readings of the clause (one bar of the hoop, as the 1993 text words it, and every leg of the hoop and its cross-ties counted). The table there says how many rows meet it; where a row does not, the tie steel of a ductile column is probably higher on the signed drawings. The model also does not check that the extra column moment capacity of a strong-column weak-beam rule is met by more than its own factor of 1.1.
- Earthquake and wind: the equivalent static method with the empirical period of a frame with infill walls and the medium-soil spectrum for every ground class. The model uses an importance factor of 1, does not raise Ah to Z ÷ 2 for periods under 0.1 s (IS 1893 cl. 6.4.2), and does not model torsion, plan or height irregularity or soil–structure interaction; only an open parking storey is treated specially (the factor 2.5 of cl. 7.10.3). A building with a soft storey that is taller than 12 m in Zone IV or V is an irregular building for which IS 1893:2002 cl. 7.8.1 asks for a dynamic analysis; the model makes none. The wind pressure follows IS 875 (Part 3):1987, with the basic wind speed from the model's table of places and a table of pressure coefficients rebuilt from a damaged scan. The height factor k2 is taken from the Class A column of Table 2 at every height and held at its 30 m value above 30 m; the code puts a building whose greatest dimension is 20 to 50 m in Class B and continues Table 2 to 50 m. The effect on the wind pressure is about 2 %.
- Editions: the model follows IS 456:2000, IS 875 (Parts 1 and 2):1987, IS 875 (Part 3):1987, IS 1893 (Part 1):2002, IS 13920:1993 and IS 10262:2009. Newer editions of four of them are now in force: IS 875 (Part 3):2015, IS 1893 (Part 1):2016, IS 13920:2016 and IS 10262:2019. A design office must work to the current editions, and the clause numbers and limits of the sheet may differ in them. Some wording in the report names IS 13920:2016, but the working follows the 1993 edition. The strong-column weak-beam factor of the model is 1.1 (its own value; the 1993 text has no such clause). A software help page reports 1.4 for the 2016 edition (cl. 7.2); the 2016 text itself was not read, so a column meant for the 2016 rule may need more moment capacity than the model gives it. Fe 500D steel is used throughout: the unamended IS 13920:1993 allows Fe 415 or lower, and its Amendment No. 2 (2002) admits Fe 500 and Fe 550 thermo-mechanically treated bars with more than 14.5 % elongation.
- Loads and ground: only residential use is assumed, with the imposed loads of IS 875 (Part 2), walls counted at 85 % of the full wall, and no water tank, lift or future floors. The ground class stands for a safe bearing capacity and a founding depth that are planning values until a soil test is done. The imposed load on a column is reduced as for IS 875 (Part 2) cl. 3.2.1, which the code allows for floors designed for 5.0 kN/m² or more (cl. 3.2.1.1); the model applies it to residential floors as designers commonly do.
- What the checks of the report mean: the statuses printed beside the checks in the report record what the tool tested. Some, such as the grade of steel and the grade of concrete for the exposure, follow from the tool's own choices and cannot fail. Where the report warns that a limit is reached (for example that the beam section limit is reached), the sections shown do not pass that check. The quantities are those of the sections shown, so they are an estimate of the steel and concrete a code-style design would need, not proof that the building passes the codes.
- Bars in a beam layer: when the model chooses the extra top bars it tests how many bars of that size fit in one layer of the beam width, but it does not count the two continuous hanging bars in that layer. In a narrow beam the bars drawn may therefore not fit in one layer with the clear gaps the code asks for (IS 456 cl. 26.3.1); a drawing would use two layers or a wider beam, which changes the steel slightly.
- Slabs, staircase and balconies: the slabs use the bending coefficients of IS 456 Annex D; the staircase and the balconies use a simple beam model. Shear, crack width and vibration are not checked. The mid-span bars run the full span without curtailment and the bar spacing is limited to 150 mm; both add steel compared with the code minimum. The loads and sizes of the staircase and the balconies are NirmanShastra choices.

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- Foundations: an isolated footing is sized for the bearing capacity assumed for the ground class and checked for bending, one-way shear and punching shear. A raft is indicative only: its thickness comes from punching shear, not from the pressure on the ground, and the pressure printed for a raft is for the service load alone. The overturning of the building by the earthquake or the wind is not added; it raises the pressure at the edge, and for a tall or narrow raft the edge pressure can exceed the capacity assumed. IS 2950 (Part 1) is the code for rafts and the sheet does not follow it. In Zones IV and V the model counts a second set of plinth beams as footing ties also under a raft; IS 1893 cl. 7.12.1 is written for individual spread footings, so under a raft that count is probably high (about 2 % of the steel in a ten-floor example). Settlement, uplift, the water table, the swelling of black cotton soil and neighbouring buildings are not considered. A soil test replaces the assumed bearing capacity.
- Quantities: bars are counted with the hooks, laps and cover worked in the sections, cut lengths are taken up to the next 25 mm, and chairs, spacers and the extra bars a drawing adds at junctions are not counted (the raft is the one place where chairs are). Built houses usually use more, which is why the report prints a range under each total. The quantities of this report are not reconciled with the reports of other NirmanShastra tools, except through the Grand Total.
- Concrete mixes: up to M20 the cement, sand and aggregate in a cubic metre are the CPWD nominal-mix figures. From M25 they are worked from IS 10262 with a typical water-cement ratio for the grade, 20 mm aggregate, zone II sand and a 100 mm slump; no target mean strength is worked out. They are for ordering. Trial batches with the real materials decide the mix to be used. IS 10262:2019 is the edition now in force.
- Clause numbers: where the SOURCE column gives a clause or table number, treat it as a pointer to check, not as a quotation. Sampled against the text of the edition named: IS 1893 (Part 1):2002, IS 13920:1993 with its Amendment No. 2, IS 875 (Part 2):1987 cl. 3.2, IS 875 (Part 3):1987 Tables 1 and 2 and cl. 5.3.2, and IS 10262:2009. The rest of IS 456:2000 and IS 875 (Part 3) Table 4, IS 1786, IS 2502, SP 34 and IS 1904 were not re-read against the standard when this sheet was last checked, and a sentence saying what a clause requires can be wrong even where its number is right. The CPWD item numbers in the descriptions of the mixes are the report's own and were not re-read. The clause numbers printed beside the checks in Section 14 are the report's own; they were not re-read, and some name the 2016 edition of IS 13920, which the tool does not follow. Where a limit is the tool's own choice the SOURCE column says so.
- Floor plans: the model fits one regular grid of bays to every floor, and the bays of each floor must fit over the bays of the floor below. Some sets of floor areas do not give bays that fit (three floors of 1,500, 1,200 and 900 sq ft are one example). The model cannot size them, and for such an input there is no report and no sheet.

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1. Your answers and what was worked out from them

The tool asks only for floors, areas, place, ground, walls, parking and balconies. Everything else on this sheet is derived from those answers by the model's own rules, which are named on each line.

What you told the tool

STEP	FORMULA	WORKING	RESULT	SOURCE
Floors you listed			**2**	Your answer
Built-up area of each floor, lowest first			**1,000, 1,000 sq ft**	Your answer
Total built-up area	A = Σ floor areas × 0.09290304	2,000 sq ft × 0.0929	**185.8 m²**	Unit conversion: 1 sq ft = 0.09290304 m²
Place			**Lucknow, Uttar Pradesh**	Your answer
Ground One of the eight answers on the form			**ordinary firm soil**	Your answer
Walls			**Brick, 230 mm outside**	Your answer
Open parking level (stilt)			**No**	Your answer
Balconies per upper floor			**None**	Your answer
Roof used as a terrace			**Yes (imposed load 1.5 kN/m²)**	Your answer
Storeys of the frame The parking level is a storey of the frame (it has columns and a roof slab) but not built-up area	F = floors listed + 1 if there is an open parking level	2 + 0	**2**	Engine rule

What the ground answer means

STEP	FORMULA	WORKING	RESULT	SOURCE
Ground condition			**ordinary firm soil**	Your answer
Safe bearing capacity assumed A soil test replaces this; every footing size depends on it			**150 kN/m²**	NirmanShastra assumption: by ground class
Founding depth (ground level to underside of the lean concrete)			**1.5 m**	NirmanShastra assumption: by ground class
Foundation type forced by the ground class Section 8 shows how the foundation type was decided			**Isolated footings unless the trial footings overlap**	NirmanShastra assumption: by ground class
Exposure condition of the concrete			**mild**	IS 456:2000 Table 3 (classes), NirmanShastra assumption (class chosen per ground)

These values are the model's planning assumptions for each ground class. They are not test results.

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Shape of the plan

STEP	FORMULA	WORKING	RESULT	SOURCE
Shape of the building plan (long side ÷ short side) No plot size was given: a plan 1.3 times as long as it is wide			**1.3**	NirmanShastra assumption

Storeys of the frame

STOREY	AREA (SQ FT)	AREA (M²)
Ground floor	1,000.0	92.9
Floor 1	1,000.0	92.9
Total of the frame	**2,000.0**	**185.8**

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2. Site and materials

The earthquake zone, the wind speed and the concrete grade follow from the place and the ground class. Each is a planning value to be confirmed by the engineer who signs the drawings.

Earthquake zone

STEP	FORMULA	WORKING	RESULT	SOURCE
Place used for the zone			**Lucknow, Uttar Pradesh**	Your answer
Seismic zone The town is in the IS 1893 Annex E list. Zone III for Lucknow (IS 1893:2002 Annex E). IS 1893:2016 is the edition in force: confirm with a local structural engineer.	Annex E town list, else typical for the state		**Zone III**	IS 1893 (Part 1):2002 Annex E (towns); IS 1893 (Part 1):2002 Fig. 1 (map)
Zone factor Z Maximum considered earthquake; the design value is Z ÷ 2			**0.16**	IS 1893 (Part 1):2002 Table 2
Detailing class Engine rule: Zone II is not detailed to IS 13920	Zone III and above: special moment-resisting frame; Zone II: ordinary		**Special moment-resisting frame, IS 13920 ductile detailing, R = 5**	IS 1893 (Part 1):2002 Table 7 (R); IS 13920:1993

Wind speed

STEP	FORMULA	WORKING	RESULT	SOURCE
Basic wind speed Vb Table value for Lucknow: a secondary source, to be confirmed against the wind map			**47 m/s**	IS 875 (Part 3):1987 Fig. 1 and Appendix A (value from a published city table)
Terrain category Open terrain with scattered obstructions: the basis of Vb and the higher of the two usual choices			**2**	IS 875 (Part 3):1987 cl. 5.3.2
Risk coefficient k1 Buildings designed for a 50-year life			**1.0**	IS 875 (Part 3):1987 cl. 5.3.1 Table 1
Topography factor k3 Level ground assumed: no hill or ridge effect			**1.0**	IS 875 (Part 3):1987 cl. 5.3.3

The 1987 edition of IS 875 (Part 3) is used. The later edition adds directionality, area-averaging and cyclonic factors that this model does not apply.

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Exposure and grade of concrete

STEP	FORMULA	WORKING	RESULT	SOURCE
Exposure condition NirmanShastra assumption: which condition each ground class implies	from the ground class		**mild**	IS 456:2000 Table 3
Minimum grade for this exposure M20; minimum cement 300 kg/m³, maximum free water-cement ratio 0.55			**20 N/mm²**	IS 456:2000 Table 5 (RCC)
Grade the model never goes below Fewer than four storeys: M20 at least			**20 N/mm²**	NirmanShastra assumption
Grade of concrete above ground M20	fck = max(Table 5 minimum, house minimum)	max(20, 20)	**20 N/mm²**	IS 456:2000 Table 5; NirmanShastra assumption
Exposure of concrete below ground Buried concrete is never rated milder than "moderate"	at least moderate		**moderate**	IS 456:2000 Table 3
Grade of concrete below ground M25	fck = max(grade above, Table 5 minimum for the buried exposure)	max(20, 25)	**25 N/mm²**	IS 456:2000 Table 5

Reinforcing steel

STEP	FORMULA	WORKING	RESULT	SOURCE
Reinforcement Fe 500D (ductile) is assumed; IS 13920 asks for ductile steel in Zones III and above			**500 N/mm²**	IS 456:2000 cl. 5.6 (Fe 500 characteristic strength)
Design strength of the steel	fyd = 0.87 fy	0.87 × 500	**435.0 N/mm²**	IS 456:2000 cl. 38.1 and Annex G
Steel strength used for stirrups and ties The design yield strength of shear reinforcement is not taken above 415 N/mm²			**415 N/mm²**	IS 456:2000 cl. 40.4
Modulus of elasticity of steel			**2,00,000 N/mm²**	IS 456:2000 cl. 5.6.3
Unit weight of reinforced concrete			**25 kN/m³**	IS 456:2000 cl. 19.2.1 and IS 875 (Part 1):1987

Concrete cover used by the model

Table 16 of IS 456 asks for a nominal cover of 20 mm for this exposure condition (mild).

MEMBER	COVER USED (MM)	SOURCE
Slab	20	NirmanShastra assumption: Table 16 mild exposure
Beam (clear cover to the stirrup)	25	SP 34 cl. 4.1(c)
Beam, centre of the bars from the face (d = D − 45)	45	Engine rule: 25 + stirrup 8 + half a 25 mm bar, rounded
Column (to the tie)	40	IS 456:2000 cl. 26.4.2.1
Footing	50	IS 456:2000 cl. 26.4.2.2

The covers above are fixed in the model and are not less than Table 16 asks for this exposure.

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3. The frame laid out

The model lays a regular grid of beams and columns over the plan, fixes the storey heights, and sets one slab thickness for the whole building from the span to depth rule of IS 456.

Grid of columns

A regular grid of equal bays is laid over the largest storey. Your own drawing will differ; the model uses the grid to size the frame, not to copy your plan.

STEP	FORMULA	WORKING	RESULT	SOURCE
Footprint of the frame (the largest storey)	A0 = largest storey area	largest of the storey areas = 92.9	**92.90 m²**	Engine rule
Length of the plan	L = √(A0 × r)	√(92.9 × 1.3)	**10.99 m**	Engine rule
Width of the plan	W = A0 ÷ L	92.9 ÷ 10.99	**8.45 m**	Engine rule
Target bay A usual residential bay is 3.0 to 4.5 m			**3.75 m**	NirmanShastra assumption
Longest bay before a middle column is added			**5.0 m**	NirmanShastra assumption
Bays along the length, first estimate	nx = round(L ÷ target bay), at least 1	round(10.99 ÷ 3.75)	**3**	Engine rule
Bays along the width, first estimate	ny = round(W ÷ target bay), at least 1	round(8.454 ÷ 3.75)	**2**	Engine rule
Bays along the length	nx increased until L ÷ nx ≤ longest bay	start 3, longest bay 5 m, L = 10.99 m	**3**	Engine rule
Bays along the width	ny increased until W ÷ ny ≤ longest bay	start 2, longest bay 5 m, W = 8.454 m	**2**	Engine rule
Span along the length (centre to centre of columns)	sx = L ÷ nx	10.99 ÷ 3	**3.66 m**	Engine rule
Span along the width (centre to centre of columns)	sy = W ÷ ny	8.454 ÷ 2	**4.23 m**	Engine rule
Storey height (floor to floor)			**3.0 m**	NirmanShastra assumption: usual residential storey
Plinth height above ground			**0.45 m**	NirmanShastra assumption

Levels

STOREY	TOP OF SLAB = PLINTH + STOREY HEIGHT × STOREYS	LEVEL ABOVE GROUND (M)
Ground floor	0.45 + 3.0 × 1	3.45
Floor 1	0.45 + 3.0 × 2	6.45

The top of the roof slab, 6.45 m above ground, is the height H used for the earthquake period and the wind.

Bays on each storey

A storey smaller than the largest keeps a block of whole bays whose area is nearest to it. The quantities that belong to the floor as a whole (beams, slab) are then multiplied by the correction shown, so that the totals agree with the floor area you entered.

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STOREY	AREA ENTERED (M²)	BAYS USED (X × Y)	AREA OF THOSE BAYS (M²)	CORRECTION = ENTERED ÷ BAYS
Ground floor	92.9	3 × 2	92.9	1.000
Floor 1	92.9	3 × 2	92.9	1.000

The search takes the (x, y) pair of bays with the smallest |bays ÷ largest-storey bays – area ratio| + 0.01 |x ÷ nx – y ÷ ny|. The floors are not forced to sit inside the floor below.

Slab thickness from the span to depth rule

STEP	FORMULA	WORKING	RESULT	SOURCE
Shorter span of the panel	lx = min(sx, sy)	min(3.663, 4.227)	**3.66 m**	IS 456:2000 cl. 23.2.1, note 1 (shorter span of a two-way slab)
Basic span ÷ effective depth Values for a simply supported and a continuous span; the cantilever value of 7 is used for balconies in Section 10	continuous: 26; simply supported: 20		**26 (the slab continues over a beam)**	IS 456:2000 cl. 23.2.1
Modification factor for the tension steel NirmanShastra assumption: the chart is not read by the model; a typical value for Fe 500 slabs is taken			**1.2**	IS 456:2000 cl. 23.2.1 (Fig. 4)
Effective depth needed	d = lx ÷ (basic ratio × modification factor)	3.663 × 1000 ÷ (26 × 1.2)	**117.4 mm**	IS 456:2000 cl. 23.2.1
Overall thickness before rounding Cover 20 mm and half of a 10 mm bar	t = d + cover + half a bar	117.4 + 20 + 5	**142.4 mm**	IS 456:2000 cl. 26.4
Slab thickness used One thickness is used for every slab of the building	t = round up to 25 mm, kept between 125 and 250 mm	min(250, max(125, roundup(142.4 ÷ 25) × 25))	**150 mm**	Engine rule

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4. Loads

Dead loads come from the slab thickness, finishes, walls and the members' own weight; imposed loads from IS 875 (Part 2); the factored combinations are those of IS 456 Table 18 with the earthquake terms of IS 1893.

Unit weights and imposed loads used

STEP	FORMULA	WORKING	RESULT	SOURCE
Reinforced concrete			**25 kN/m³**	IS 456:2000 cl. 19.2.1; IS 875 (Part 1):1987 Table 1
Brick masonry			**18.85 kN/m³**	IS 875 (Part 1):1987 Table 1 (1920 kg/m³)
Cement plaster			**20.4 kN/m³**	IS 875 (Part 1):1987 Table 1
Floor finish on the floors Flooring and its bedding; the finish values of IS 875 (Part 1) are not read by the model			**1.5 kN/m²**	NirmanShastra assumption
Roof finish (waterproofing and brick-bat coba)			**2.0 kN/m²**	NirmanShastra assumption
Ceiling plaster under every slab 12 mm of cement plaster, 0.012 × 20.4 = 0.245, taken as 0.25			**0.25 kN/m²**	NirmanShastra assumption
Imposed load on the floors Residential rooms			**2.0 kN/m²**	IS 875 (Part 2):1987 Table 1
Imposed load on the roof Roof used as a terrace (access provided)			**1.50 kN/m²**	IS 875 (Part 2):1987 Table 2
Share of the imposed load that counts as mass in an earthquake For imposed loads up to 3 kN/m²; none on the roof (cl. 7.3.2)			**0.25**	IS 1893 (Part 1):2002 Table 8 and cl. 7.3.1

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Slab loads per square metre

STEP	FORMULA	WORKING	RESULT	SOURCE
Dead load of a floor slab (a floor above it)	g = γ t + floor finish + ceiling plaster	25 × 0.15 + 1.5 + 0.25	**5.500 kN/m²**	IS 875 (Part 1):1987; NirmanShastra assumption (finish)
Imposed load of a floor slab			**2.00 kN/m²**	IS 875 (Part 2):1987 Table 1
Dead load of the roof slab	g = γ t + roof finish + ceiling plaster	25 × 0.15 + 2 + 0.25	**6.000 kN/m²**	IS 875 (Part 1):1987; NirmanShastra assumption (finish)
Imposed load of the roof slab			**1.50 kN/m²**	IS 875 (Part 2):1987 Table 2

A bay with a floor above it is loaded as a floor; the top storey, and any bay not covered by the storey above it, is loaded as a roof.

Wall loads on beams

STEP	FORMULA	WORKING	RESULT	SOURCE
Clear wall height on a beam			**2.60 m**	NirmanShastra assumption: storey height less 0.4 m for the beam depth, before the beam is designed
Allowance for doors and windows The wall is counted at 85 % of its full weight			**0.85**	NirmanShastra assumption
Outer wall per metre run of beam Wall 230 mm thick, plaster 32 mm in all on the two faces	w = (t γ + plaster γp) × h × 0.85	(0.23 × 18.85 + 0.032 × 20.4) × 2.6 × 0.85	**11.024 kN/m**	IS 875 (Part 1):1987 Table 1; NirmanShastra assumption
Inner partition per metre run of beam A 115 mm brick partition on half of the inner beam lines	w = presence × (t γ + plaster γp) × h × 0.85	0.5 × (0.115 × 18.85 + 0.024 × 20.4) × 2.6 × 0.85	**2.936 kN/m**	IS 875 (Part 1):1987 Table 1; NirmanShastra assumption
Parapet on the roof edge, per metre A 115 mm brick parapet, plastered both faces	w = t γ + plaster γp	0.115 × 18.85 + 0.032 × 20.4	**2.821 kN/m**	IS 875 (Part 1):1987 Table 1; NirmanShastra assumption

A wall is loaded on the beam of the storey below it. The ground-storey walls stand on the plinth beams, not on the frame, and enter only the seismic weight. With an open parking level there is no wall on the parking level.

Loads on the governing edge beam

The slab load reaches a beam as a triangle on the short side of a panel and a trapezoid on the long side. The model replaces each by an equal uniform load, one value that gives the same bending moment and one that gives the same shear. The beam's own weight is added when its depth is known (Section 6).

STEP	FORMULA	WORKING	RESULT	SOURCE
Beam On the outer wall line; the beam that sets the size for its type			**along the width, level 1, span 1 of 2 in its line, 4.23 m**	Engine rule
Bay beside the beam (bay 1,1)	Floor slab: dead 5.500 kN/m², imposed 2.00 kN/m². Short side 3.66 m, long side 4.23 m. The beam is on the long side, so the slab load comes to it as a trapezoid.			IS 456:2000 cl. 24.5, Fig. 7 (loads on supporting beams)
Equivalent uniform dead load, for the moment (bay 1,1)	weq = (w lx ÷ 6)(3 − 1/α²)	(5.5 × 3.663 ÷ 6) × (3 − 1 ÷ 1.154²)	**7.552 kN/m**	IS 456:2000 cl. 24.5, Fig. 7; equivalent uniform load: standard formula
Equivalent uniform dead load, for the shear (bay 1,1)	weq = (w lx ÷ 2)(1 − 1/(2α))	(5.5 × 3.663 ÷ 2) × (1 − 1 ÷ (2 × 1.154))	**5.709 kN/m**	IS 456:2000 cl. 24.5, Fig. 7; equivalent uniform load: standard formula
Equivalent uniform imposed load, for the moment (bay 1,1)	weq = (w lx ÷ 6)(3 − 1/α²)	(2 × 3.663 ÷ 6) × (3 − 1 ÷ 1.154²)	**2.746 kN/m**	IS 456:2000 cl. 24.5, Fig. 7; equivalent uniform load: standard formula
Equivalent uniform imposed load, for the shear (bay 1,1)	weq = (w lx ÷ 2)(1 − 1/(2α))	(2 × 3.663 ÷ 2) × (1 − 1 ÷ (2 × 1.154))	**2.076 kN/m**	IS 456:2000 cl. 24.5, Fig. 7; equivalent uniform load: standard formula
Wall on this beam Loaded value 11.024 kN/m (from the wall loads above)	by what stands above it		**outer wall of the storey above**	Engine rule
Dead load for the moment (slab + balcony + wall)	wd = Σ weq + wall	7.5517 + 11.024	**18.576 kN/m**	Engine rule
Dead load for the shear (slab + balcony + wall)	wdv = Σ weq + wall	5.70855 + 11.0241	**16.733 kN/m**	Engine rule

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Imposed load for the moment	wl = Σ weq	2.746	**2.746 kN/m**	Engine rule
Imposed load for the shear	wlv = Σ weq	2.076	**2.076 kN/m**	Engine rule

Loads on the governing inner beam

The slab load reaches a beam as a triangle on the short side of a panel and a trapezoid on the long side. The model replaces each by an equal uniform load, one value that gives the same bending moment and one that gives the same shear. The beam's own weight is added when its depth is known (Section 6).

STEP	FORMULA	WORKING	RESULT	SOURCE
Beam An inner beam; the beam that sets the size for its type			**along the width, level 1, span 1 of 2 in its line, 4.23 m**	Engine rule
Bay beside the beam (bay 2,1)	Floor slab: dead 5.500 kN/m², imposed 2.00 kN/m². Short side 3.66 m, long side 4.23 m. The beam is on the long side, so the slab load comes to it as a trapezoid.			IS 456:2000 cl. 24.5, Fig. 7 (loads on supporting beams)
Equivalent uniform dead load, for the moment (bay 2,1)	weq = (w lx ÷ 6)(3 − 1/α²)	(5.5 × 3.663 ÷ 6) × (3 − 1 ÷ 1.154²)	**7.552 kN/m**	IS 456:2000 cl. 24.5, Fig. 7; equivalent uniform load: standard formula
Equivalent uniform dead load, for the shear (bay 2,1)	weq = (w lx ÷ 2)(1 − 1/(2α))	(5.5 × 3.663 ÷ 2) × (1 − 1 ÷ (2 × 1.154))	**5.709 kN/m**	IS 456:2000 cl. 24.5, Fig. 7; equivalent uniform load: standard formula
Equivalent uniform imposed load, for the moment (bay 2,1)	weq = (w lx ÷ 6)(3 − 1/α²)	(2 × 3.663 ÷ 6) × (3 − 1 ÷ 1.154²)	**2.746 kN/m**	IS 456:2000 cl. 24.5, Fig. 7; equivalent uniform load: standard formula
Equivalent uniform imposed load, for the shear (bay 2,1)	weq = (w lx ÷ 2)(1 − 1/(2α))	(2 × 3.663 ÷ 2) × (1 − 1 ÷ (2 × 1.154))	**2.076 kN/m**	IS 456:2000 cl. 24.5, Fig. 7; equivalent uniform load: standard formula
Bay beside the beam (bay 1,1)	Floor slab: dead 5.500 kN/m², imposed 2.00 kN/m². Short side 3.66 m, long side 4.23 m. The beam is on the long side, so the slab load comes to it as a trapezoid.			IS 456:2000 cl. 24.5, Fig. 7 (loads on supporting beams)
Equivalent uniform dead load, for the moment (bay 1,1)	weq = (w lx ÷ 6)(3 − 1/α²)	(5.5 × 3.663 ÷ 6) × (3 − 1 ÷ 1.154²)	**7.552 kN/m**	IS 456:2000 cl. 24.5, Fig. 7; equivalent uniform load: standard formula
Equivalent uniform dead load, for the shear (bay 1,1)	weq = (w lx ÷ 2)(1 − 1/(2α))	(5.5 × 3.663 ÷ 2) × (1 − 1 ÷ (2 × 1.154))	**5.709 kN/m**	IS 456:2000 cl. 24.5, Fig. 7; equivalent uniform load: standard formula
Equivalent uniform imposed load, for the moment (bay 1,1)	weq = (w lx ÷ 6)(3 − 1/α²)	(2 × 3.663 ÷ 6) × (3 − 1 ÷ 1.154²)	**2.746 kN/m**	IS 456:2000 cl. 24.5, Fig. 7; equivalent uniform load: standard formula
Equivalent uniform imposed load, for the shear (bay 1,1)	weq = (w lx ÷ 2)(1 − 1/(2α))	(2 × 3.663 ÷ 2) × (1 − 1 ÷ (2 × 1.154))	**2.076 kN/m**	IS 456:2000 cl. 24.5, Fig. 7; equivalent uniform load: standard formula
Wall on this beam Loaded value 2.936 kN/m (from the wall loads above)	by what stands above it		**inner partition of the storey above**	Engine rule
Dead load for the moment (slab + balcony + wall)	wd = Σ weq + wall	15.1034 + 2.93637	**18.040 kN/m**	Engine rule
Dead load for the shear (slab + balcony + wall)	wdv = Σ weq + wall	11.417 + 2.9364	**14.353 kN/m**	Engine rule
Imposed load for the moment	wl = Σ weq	5.492	**5.492 kN/m**	Engine rule
Imposed load for the shear	wlv = Σ weq	4.152	**4.152 kN/m**	Engine rule

Reduction of imposed load on columns

The imposed load on a column is reduced by the number of floors it carries.

FLOORS CARRIED BY THE COLUMN (ROOF INCLUDED)	REDUCTION OF THE IMPOSED LOAD

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1	0 %
2	10 %
3	20 %
4	30 %
5 or more	40 %

IS 875 (Part 2):1987 cl. 3.2.1 lets a designer reduce the imposed load on columns in this way. The model applies it to columns only. Beams and slabs take the full imposed load (cl. 3.2.2 would allow a small reduction on large beam areas: not taken, which is on the safe side). The model stops at 40 %; the code allows 50 % for a column that carries more than 10 floors, so a taller building is on the safe side. Cl. 3.2.1.1 allows the reduction where a floor is designed for 5.0 kN/m² or more, or where the loading is not less than if all floors had been designed for that; the model applies it to residential floors as designers commonly do.

Factored combinations of loads

Limit state design takes the least favourable of these four combinations for every member. EL is the earthquake or the wind, whichever is the larger lateral force storey by storey: they are never added together.

CASE	COMBINATION	MEANING	SOURCE
1	1.5 (DL + LL)	Gravity only	IS 456:2000 Table 18; IS 1893 (Part 1):2002 cl. 6.3.1.2
2	1.2 (DL + LL ± EL)	Gravity with the earthquake	IS 456:2000 Table 18; IS 1893 (Part 1):2002 cl. 6.3.1.2
3	1.5 (DL ± EL)	Dead load with the earthquake	IS 456:2000 Table 18; IS 1893 (Part 1):2002 cl. 6.3.1.2
4	0.9 DL ± 1.5 EL	Overturning and moment reversal	IS 456:2000 Table 18; IS 1893 (Part 1):2002 cl. 6.3.1.2

Beams (Section 6): hogging moment = the largest of 1.5 Ms, 1.2 (Ms + ME) and 1.5 (rD Ms + ME); sagging at a support = 1.5 ME − 0.9 rD Ms, never less than half the hogging moment in Zones III and above; mid-span sagging = 1.5 Ms. Ms is the gravity moment from IS 456 Table 12, ME the earthquake moment from the portal method and rD the dead share of the load. Shear = the larger of 1.5 Vg and 1.2 (Vg + VE). Columns (Section 7): the seven cases listed there, with 100 % of the lateral force one way and 30 % the other (IS 1893 cl. 6.3.2.2).

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5. Lateral loads: earthquake and wind

The frame is designed for the larger of the earthquake and the wind in each direction. The earthquake is worked by the equivalent static method of IS 1893 (Part 1):2002 and the wind by IS 875 (Part 3):1987. The forces on the frame come from the portal method, a hand method for regular frames: they are not a computer analysis of the frame.

Seismic weight: worked example for the lowest level

The seismic weight of a level is its dead load plus a share of the imposed load, with half of the walls and columns above and below it (IS 1893 cl. 7.4). The weights used for the final earthquake forces come from the member sizes of the model's first design pass; the second pass then designs the members for those forces and its own weights are not fed back again.

STEP	FORMULA	WORKING	RESULT	SOURCE
Worked example	Level 0 is the top of ground floor. It has 6 bays of 3.66 × 4.23 m.			Engine rule
Slab: dead load plus 25 % of the imposed load Bays under a floor above carry 25 % of the imposed load; bays under the open sky (the roof) carry none	Ws = bays × sx × sy × (g + 0.25 q)	6 × 15.484 × (5.5 + 0.25 × 2) + 0 × 15.484 × 0	**557.4 kN**	IS 1893 (Part 1):2002 cl. 7.3.1, 7.3.2, 7.4 and Table 8
Beams: own weight The beam sizes are those of the first design pass	Wb = Σ (25 b (D − t) × L)	17 beams of the first pass, total length 66.784 m, weighted mean 1.3113 kN/m	**87.6 kN**	IS 875 (Part 1):1987; Engine rule
Columns: own weight, half of each storey The column sizes are those of the first design pass	Wc = ½ Σ (25 b D hs) of the storey below + ½ of the storey above	½ × 90 + ½ × 90	**90.0 kN**	IS 1893 (Part 1):2002 cl. 7.4.1 (half the weight of columns and walls above and below the level)
Walls: half of the storey below and half of the storey above The ground-storey walls are counted on the plinth beams	Ww = ½ (walls of storey 0) + ½ (walls of storey 1)	½ × 510.6 + ½ × 510.6	**510.6 kN**	IS 1893 (Part 1):2002 cl. 7.4.1
Seismic weight of level 0	W0 = slabs + beams + parapet + walls + columns	557.4 + 87.58 + 0 + 510.6 + 90	**1,245.6 kN**	IS 1893 (Part 1):2002 cl. 7.4

Seismic weight of every level (kN)

LEVEL	SLABS	BEAMS	PARAPET	WALLS	COLUMNS	WEIGHT W
Level 1	557.4	87.6	0.0	510.6	90.0	1,245.6
Roof	557.4	69.8	109.7	255.3	45.0	1,037.2
Total						**2,282.8**

Each figure was rebuilt from the loads of Section 4 and the first-pass member sizes and agrees with the model's own. Imposed load is 25 % on floors and nil on the roof.

Earthquake: design coefficient

Equivalent static method: the earthquake is replaced by a set of horizontal forces found from the weight of the building and a coefficient that depends on the zone, the type of frame and the natural period.

STEP	FORMULA	WORKING	RESULT	SOURCE
Zone factor Z			**0.16**	IS 1893 (Part 1):2002 Table 2

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Response reduction factor R Special moment-resisting frame: Zone III and above, ductile detailing to IS 13920			**5**	IS 1893 (Part 1):2002 Table 7
Importance factor I Residential building. The model has no importance factor in its formula; for I = 1.0 that is the same. A building of more than ordinary importance (hospital, school, assembly hall) needs I = 1.5			**1.0**	IS 1893 (Part 1):2002 Table 6
Height of the building H (top of roof slab above ground) The parapet and head-room are not counted			**6.45 m**	IS 1893 (Part 1):2002 cl. 7.6.2
Natural period along x d = 10.99 m, the base dimension of the building along x. The formula is for a frame with brick infill	T = 0.09 H ÷ √d	0.09 × 6.45 ÷ √10.99	**0.175 s**	IS 1893 (Part 1):2002 cl. 7.6.2
Spectral acceleration coefficient along x The medium-soil curve is used for every ground class	Sa/g = 1 + 15T (T < 0.10); 2.5 (0.10 ≤ T ≤ 0.55); 1.36 ÷ T (T > 0.55)	T = 0.175 s	**2.500**	IS 1893 (Part 1):2002 cl. 6.4.2 and Fig. 2 (medium soil)
Design horizontal coefficient along x	Ah = (Z ÷ 2) × (I ÷ R) × (Sa/g)	(0.16 ÷ 2) × (1 ÷ 5) × 2.5	**0.0400**	IS 1893 (Part 1):2002 cl. 6.4.2
Natural period along y d = 8.45 m, the base dimension of the building along y. The formula is for a frame with brick infill	T = 0.09 H ÷ √d	0.09 × 6.45 ÷ √8.454	**0.200 s**	IS 1893 (Part 1):2002 cl. 7.6.2
Spectral acceleration coefficient along y The medium-soil curve is used for every ground class	Sa/g = 1 + 15T (T < 0.10); 2.5 (0.10 ≤ T ≤ 0.55); 1.36 ÷ T (T > 0.55)	T = 0.2 s	**2.500**	IS 1893 (Part 1):2002 cl. 6.4.2 and Fig. 2 (medium soil)
Design horizontal coefficient along y	Ah = (Z ÷ 2) × (I ÷ R) × (Sa/g)	(0.16 ÷ 2) × (1 ÷ 5) × 2.5	**0.0400**	IS 1893 (Part 1):2002 cl. 6.4.2

Earthquake: base shear

STEP	FORMULA	WORKING	RESULT	SOURCE
Σ W h² over all levels	Σ Wi hi²	57,974	**57,974 kN·m²**	IS 1893 (Part 1):2002 cl. 7.7.1
Design base shear along x	VB = Ah × W	0.04 × 2,283	**91.3 kN**	IS 1893 (Part 1):2002 cl. 7.5.3
Design base shear along y	VB = Ah × W	0.04 × 2,283	**91.3 kN**	IS 1893 (Part 1):2002 cl. 7.5.3

Earthquake: force at each level and shear in each storey (kN)

The base shear is shared between the levels in proportion to W h²: force at a level = VB × W h² ÷ Σ W h² (IS 1893 cl. 7.7.1). The shear in a storey is the sum of the forces above it.

LEVEL	HEIGHT H (M)	WEIGHT W	FORCE QX	FORCE QY	STOREY SHEAR VX	STOREY SHEAR VY
Level 1	3.45	1,245.6	23.4	23.4	91.3	91.3
Roof	6.45	1,037.2	68.0	68.0	68.0	68.0

Wind: pressure and base shear

The wind pressure is worked from IS 875 (Part 3), 1987 edition, as a check beside the earthquake force.

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STEP	FORMULA	WORKING	RESULT	SOURCE
Basic wind speed Vb			**47 m/s**	IS 875 (Part 3):1987 cl. 5.2
Method	The wind pressure at each level is found from the design wind speed at that height, multiplied by the net pressure coefficient of the whole building, the height each level looks after and the width of the wall it faces.			IS 875 (Part 3):1987
Height factor k2 at the roof The model reads the Class A column at every height. Table 2 heights 10, 15, 20, 30 m give 1, 1.05, 1.07, 1.12. IS 875 (Part 3) cl. 5.3.2.2 gives Class A to a building whose greatest dimension is under 20 m and Class B to one of 20 to 50 m.	k2 from Table 2 (the Class A column of the terrain category), interpolated between the table heights	z = 6.45 m between table heights	**1.0000**	IS 875 (Part 3):1987 Table 2; cl. 5.3.2
Design wind speed at the roof	Vz = Vb × k1 × k2 × k3	47 × 1.0 × 1 × 1.0	**47.00 m/s**	IS 875 (Part 3):1987 cl. 5.3
Design wind pressure at the roof	pz = 0.6 Vz²	0.6 × 47² ÷ 1000	**1.325 kN/m²**	IS 875 (Part 3):1987 cl. 5.4
Shape of the building	Height ÷ shorter side h/w = 0.76 and longer ÷ shorter side l/w = 1.30 select row 2, column 1 of the wall pressure table.			IS 875 (Part 3):1987 Table 4
Windward wall coefficient			**0.70**	IS 875 (Part 3):1987 Table 4 (values rebuilt from a damaged scan)
Leeward wall suction (the larger of the two wind angles)			**0.25**	IS 875 (Part 3):1987 Table 4 (values rebuilt from a damaged scan)
Net coefficient on the walls Pressure and suction act together on the two faces of the building	ct = windward + leeward	0.7 + 0.25	**0.95**	IS 875 (Part 3):1987 Table 4
Wind base shear along x	Vw = Σ forces on all levels	60.94	**60.9 kN**	IS 875 (Part 3):1987 cl. 6.3
Wind base shear along y	Vw = Σ forces on all levels	79.22	**79.2 kN**	IS 875 (Part 3):1987 cl. 6.3

Wind force at each level

Force at a level = pz × ct × (height the level looks after) × (width of the wall facing the wind). The height a level looks after runs from half-way down to the level below to half-way up to the level above; the roof level also takes a 1 m parapet.

LEVEL	HEIGHT Z (M)	K2	VZ (M/S)	PZ (KN/M²)	HEIGHT LOOKED AFTER (M)	WALL WIDTH, WIND ALONG X (M)	FORCE FX (KN)	WALL WIDTH, WIND ALONG Y (M)	FORCE FY (KN)
Level 1	3.45	1.000	47.00	1.325	3.23	8.45	34.3	11.0	44.6
Roof	6.45	1.000	47.00	1.325	2.50	8.45	26.6	11.0	34.6

Which load governs

Storey by storey the design takes the larger of the earthquake shear and the wind shear and never adds them (IS 1893 cl. 6.2(b): an earthquake is not taken to occur together with the design wind).

STEP	FORMULA	WORKING	RESULT	SOURCE
Wind base shear ÷ earthquake base shear (the worse direction)	max(Vw,x ÷ VB,x ; Vw,y ÷ VB,y)	max(60.94 ÷ 91.31; 79.22 ÷ 91.31)	**0.868**	Engine rule

DIRECTION	EARTHQUAKE BASE SHEAR (KN)	WIND BASE SHEAR (KN)	GOVERNS AT THE BASE
Along x	91.3	60.9	Earthquake
Along y	91.3	79.2	Earthquake

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6. Beam design

Each beam is designed for bending and shear on the loads of Section 4 and the lateral moments of Section 5. The search starts at a depth of span ÷ 13 and goes deeper until the beam passes. The two beams that set the size of their type are worked in full; the table at the end lists every beam.

What the beam design rests on

STEP	FORMULA	WORKING	RESULT	SOURCE
Concrete grade of the frame			**20 N/mm²**	M20: Section 2
Steel			**500 N/mm²**	IS 456:2000 cl. 5.6: Fe 500D assumed
Cover to the stirrups The cover for beams in the model is a fixed 25 mm; the exposure class of Section 2 is used for the grade only			**25 mm**	SP 34:1987 cl. 4.1(c): beam cover not under 25 mm
Effective depth below the overall depth			**45 mm**	Engine rule: d = D – 45 (cover 25 + stirrup 8 + half a 25 mm bar, rounded)
Largest depth tried If a beam still fails at this depth the model warns that a deeper section or a higher grade will be needed			**650 mm**	Engine rule
Moment coefficients, continuous beam Single span: mid-span 1/10, supports 1/16 (NirmanShastra assumption)			**mid-span: end span 1/12, interior span 1/16; supports: outer 1/16, next to the outer 1/10, others 1/12**	IS 456:2000 cl. 22.5.1, Table 12 (dead load with fixed imposed load)
Load combinations			**1.5 (DL + LL); 1.2 (DL + LL ± EL); 1.5 (DL ± EL); 0.9 DL ± 1.5 EL**	IS 456:2000 Table 18; IS 1893 (Part 1):2002 cl. 6.3.1.2
Ductile detailing Bottom steel at a support at least half the top steel; stirrups closely spaced over 2 d at each end; shear from the beam's own capacity			**Yes: Zone III and above**	IS 13920:1993

Beam on the outer wall line: the beam and its size

STEP	FORMULA	WORKING	RESULT	SOURCE
Beam On the outer wall line. This is the beam that sets the size for its type. All beams of the type are in the table at the end of this section			**along the width, level 1, span 1 of 2 in its line**	Engine rule
Span, centre to centre			**4.23 m**	Section 3: the grid
Width of beam b Brick wall: 230 mm			**230 mm**	NirmanShastra assumption: the wall thickness, so that the beam does not show beyond the wall

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Column size assumed at each end of the beam The beams are designed before the columns, so the model assumes a column size by the number of floors it carries. The columns are then designed in Section 7			**300 mm**	Engine rule: estimated size
Clear span	Lclear = L – (cl + cr) ÷ 2	4.227 – (300 + 300) ÷ 2000	**3.927 m**	Engine rule
Slab thickness			**150 mm**	Section 3
Concrete grade			**20 N/mm²**	M20: Section 2
Steel strength fy (main bars)			**500 N/mm²**	IS 456:2000 cl. 5.6
Steel strength fy for stirrups For stirrups fy is not taken above 415 N/mm²			**415 N/mm²**	IS 456:2000 cl. 40.4
First trial depth	D = span ÷ 13, up to the next 25 mm, not under 300 mm	max(300; ceil(4.227 × 1000 ÷ 13 ÷ 25) × 25)	**350 mm**	Engine rule (starting point of the search; IS 456 cl. 23.2.1 span/depth ratios are checked below)
Depth search	The depth goes up in steps of 25 mm, from the first trial to at most 650 mm, until three checks pass together: the bending steel fits as a beam (not over-reinforced), the shear stress is under the Table 20 maximum, and the span to depth ratio is within the limit. Effective depth d = D – 45 mm (cover 25 mm, stirrup 8 mm, half a 25 mm bar, rounded).			IS 456:2000 cl. 23.2.1, cl. 40.2.3 and Table 20; Engine rule

Beam on the outer wall line: depth search

Each row is one trial depth. The full moments and shears for the last row are worked below.

D (MM)	D (MM)	OWN WEIGHT (KN/M)	SHEAR STRESS (N/MM²)	LARGEST SHEAR STRESS ALLOWED (N/MM²)	SPAN ÷ D	ALLOWED	BENDING OK	SHEAR OK	DEFLECTION OK
350	305	1.150	0.92	2.80	13.9	22	No	Yes	Yes
375	330	1.294	0.86	2.80	12.8	22	No	Yes	Yes
400	355	1.438	0.80	2.80	11.9	22	Yes	Yes	Yes

Span ÷ d allowed: 22 for an end or single span and 26 for an interior span. These are the basic ratios of IS 456 cl. 23.2.1 (20 for a simply supported beam, 26 for a continuous one) with an assumed modification factor of about 1.1 for the steel stress; the factor is not computed from the steel provided, which is an assumption.

Beam on the outer wall line: loads and gravity moments

STEP	FORMULA	WORKING	RESULT	SOURCE
Dead load for the moment: slab + wall (+ balcony)			**18.576 kN/m**	Section 4: equivalent uniform load
Imposed load for the moment			**2.746 kN/m**	Section 4
Dead load for the shear: slab + wall (+ balcony)			**16.733 kN/m**	Section 4
Imposed load for the shear			**2.076 kN/m**	Section 4
Own weight of the beam below the slab	ws = 25 × b × (D – t)	25 × 230 ÷ 1000 × (400 – 150) ÷ 1000	**1.438 kN/m**	IS 456:2000 cl. 19.2.1 (25 kN/m³)
Total dead load	wd = dead load + own weight	18.5758 + 1.4375	**20.013 kN/m**	Engine rule
Total service load	w = wd + wl	20.013 + 2.7461	**22.759 kN/m**	Engine rule

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Dead share of the load Used to take only the dead part of the gravity moment in the load cases where the imposed load is left out	rD = wd ÷ w	20.013 ÷ 22.759	**0.8793**	Engine rule
Moment coefficient at mid-span			**0.0833**	IS 456:2000 cl. 22.5.1, Table 12 (dead load with fixed imposed load): near the middle of an end span, 1/12
Moment coefficient at the left support			**0.0625**	NirmanShastra assumption: 1/16 at an outer support of a monolithic frame (IS 456 cl. 22.5.2 gives wL²/24 only where the end is built into masonry)
Moment coefficient at the right support			**0.1000**	IS 456:2000 cl. 22.5.1, Table 12 (dead load with fixed imposed load): support next to the end support, 1/10
Gravity moment at mid-span	Ms = c × w × L²	0.08333 × 22.7594 × 4.22682²	**33.88 kN·m**	IS 456:2000 cl. 22.5.1, Table 12 (dead load with fixed imposed load)
Gravity moment at the left support	Ms = c × w × L²	0.0625 × 22.759 × 4.2268²	**25.41 kN·m**	IS 456:2000 cl. 22.5.1, Table 12 (dead load with fixed imposed load)
Gravity moment at the right support	Ms = c × w × L²	0.1 × 22.759 × 4.2268²	**40.66 kN·m**	IS 456:2000 cl. 22.5.1, Table 12 (dead load with fixed imposed load)

The coefficients assume a continuous beam with equal spans. Each support of a real frame is only partly fixed, so the coefficients are an approximation (see the limits at the start of the sheet).

Beam on the outer wall line: lateral moments at the ends

The lateral force (the larger of earthquake and wind, Section 5) bends the beams as well as the columns. The column moments below come from the portal method; the working is shown for the left end and the right end is the same method.

STEP	FORMULA	WORKING	RESULT	SOURCE
Shear of one frame, lateral load along y (left joint, column below) 4 frames in this direction on this storey	Vf = V ÷ number of frames	91.31 ÷ 4	**22.83 kN**	Engine rule: the storey shear is shared equally between the frames
Shear in the column (left joint, column below) An outer column carries half the shear of an inner column; 2 bays in the frame	Vc = Vf ÷ (2 nb)	22.828 ÷ (2 × 2)	**5.707 kN**	Portal method (standard approximate analysis)
Column end moment from the lateral load along y (left joint, column below)	M = Vc × h ÷ 2	5.7069 × 3 ÷ 2	**8.560 kN·m**	Portal method: contraflexure at mid-height
Joint moment at the left end	Mj = Mcol,below + a × Mcol,above	8.5604 + 1 × 6.3712	**14.932 kN·m**	Engine rule: the beam takes the sum of the column moments above and below the joint
Earthquake (or wind) moment at the left end of the beam The joint is on the outside of the frame: one beam	ME = Mj ÷ number of beams meeting at the joint	14.932 ÷ 1	**14.932 kN·m**	Engine rule: portal method, joint moment shared equally
Joint moment at the right end	Mj = Mcol,below + a × Mcol,above	17.121 + 1 × 12.742	**29.863 kN·m**	Engine rule: the beam takes the sum of the column moments above and below the joint

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Earthquake (or wind) moment at the right end of the beam	ME = Mj ÷ number of beams meeting at the joint	29.863 ÷ 2	**14.932 kN·m**	Engine rule: portal method, joint moment shared equally

Beam on the outer wall line: design moments

Hogging is tension on top (at the supports), sagging is tension at the bottom. Each figure is the largest from the load combinations of Section 4.

STEP	FORMULA	WORKING	RESULT	SOURCE
Design hogging moment at the left support	Mu = max(1.5 Ms ; 1.2 (Ms + ME) ; 1.5 (rD Ms + ME))	max(1.5 × 25.414; 1.2 × (25.414 + 14.932); 1.5 × (0.8793 × 25.414 + 14.932))	**55.92 kN·m**	IS 456:2000 Table 18; IS 1893 (Part 1):2002 cl. 6.3.1.2
Design hogging moment at the right support	Mu = max(1.5 Ms ; 1.2 (Ms + ME) ; 1.5 (rD Ms + ME))	max(1.5 × 40.662; 1.2 × (40.662 + 14.932); 1.5 × (0.8793 × 40.662 + 14.932))	**76.03 kN·m**	IS 456:2000 Table 18; IS 1893 (Part 1):2002 cl. 6.3.1.2
Sagging moment at the left support (reversal)	Mu = max(0 ; 1.5 ME − 0.9 rD Ms)	max(0; 1.5 × 14.9316 − 0.9 × 0.87934 × 25.4137)	**2.28 kN·m**	IS 456:2000 Table 18; IS 1893 (Part 1):2002 cl. 6.3.1.2 (0.9 DL + 1.5 EL)
Sagging moment at the right support (reversal)	Mu = max(0 ; 1.5 ME − 0.9 rD Ms)	max(0; 1.5 × 14.93 − 0.9 × 0.879 × 40.66)	**0.00 kN·m**	IS 456:2000 Table 18; IS 1893 (Part 1):2002 cl. 6.3.1.2 (0.9 DL + 1.5 EL)
Sagging moment at the left support, ductile rule At the face of a joint the bottom steel must be at least half the top steel	Mu = max(above ; 0.5 × hogging)	max(2.285; 0.5 × 55.92)	**27.96 kN·m**	IS 13920:1993 cl. 6.2.3
Sagging moment at the right support, ductile rule	Mu = max(above ; 0.5 × hogging)	max(0; 0.5 × 76.03)	**38.02 kN·m**	IS 13920:1993 cl. 6.2.3
Design sagging moment at mid-span	Mu = 1.5 Ms	1.5 × 33.885	**50.83 kN·m**	IS 456:2000 Table 18 (1.5 (DL + LL))

Beam on the outer wall line: steel required for bending

STEP	FORMULA	WORKING	RESULT	SOURCE
Limiting moment of resistance of the section xu,max/d = 0.46 for Fe 500 (IS 456 cl. 38.1); a larger moment needs compression steel	Mu,lim = 0.36 fck b (xu,max/d) d² (1 − 0.42 xu,max/d)	0.36 × 20 × 230 × 0.46 × 355² × (1 − 0.42 × 0.46) ÷ 10^6	**77.45 kN·m**	IS 456:2000 Annex G, cl. G-1.1(c)
Steel for mid-span sagging	Ast = (0.5 fck ÷ fy) (1 − √(1 − 4.6 Mu ÷ (fck b d²))) b d	(0.5 × 20 ÷ 500) × (1 − √(1 − 4.6 × 50.83 × 10^6 ÷ (20 × 230 × 355²))) × 230 × 355	**372 mm²**	IS 456:2000 Annex G, cl. G-1.1(b)
Steel for hogging at the left support	Ast = (0.5 fck ÷ fy) (1 − √(1 − 4.6 Mu ÷ (fck b d²))) b d	(0.5 × 20 ÷ 500) × (1 − √(1 − 4.6 × 55.92 × 10^6 ÷ (20 × 230 × 355²))) × 230 × 355	**415 mm²**	IS 456:2000 Annex G, cl. G-1.1(b)
Steel for hogging at the right support	Ast = (0.5 fck ÷ fy) (1 − √(1 − 4.6 Mu ÷ (fck b d²))) b d	(0.5 × 20 ÷ 500) × (1 − √(1 − 4.6 × 76.03 × 10^6 ÷ (20 × 230 × 355²))) × 230 × 355	**604 mm²**	IS 456:2000 Annex G, cl. G-1.1(b)
Steel for sagging at the left support	Ast = (0.5 fck ÷ fy) (1 − √(1 − 4.6 Mu ÷ (fck b d²))) b d	(0.5 × 20 ÷ 500) × (1 − √(1 − 4.6 × 27.96 × 10^6 ÷ (20 × 230 × 355²))) × 230 × 355	**192 mm²**	IS 456:2000 Annex G, cl. G-1.1(b)
Steel for sagging at the right support	Ast = (0.5 fck ÷ fy) (1 − √(1 − 4.6 Mu ÷ (fck b d²))) b d	(0.5 × 20 ÷ 500) × (1 − √(1 − 4.6 × 38.02 × 10^6 ÷ (20 × 230 × 355²))) × 230 × 355	**268 mm²**	IS 456:2000 Annex G, cl. G-1.1(b)
Minimum tension steel	Ast,min = 0.85 b d ÷ fy	0.85 × 230 × 355 ÷ 500	**139 mm²**	IS 456:2000 cl. 26.5.1.1(a)

These are areas of steel in mm²; the bars chosen to provide them follow.

Beam on the outer wall line: bars chosen

STEP	FORMULA	WORKING	RESULT	SOURCE

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Bottom steel required	max(mid-span ; sagging at supports ; minimum)	max(371.6; 138.8; 192.5; 268.3)	**372 mm²**	Engine rule
Bottom bars chosen A layer of a 230 mm beam holds at most 4 bars of 12 mm (clear spacing not under the larger of the bar size and 25 mm, cover 25 mm, stirrup 8 mm; site practice limits it to 4 bars)	smallest size from 12, 16, 20, 25, 32 mm that fits in one layer; at least 2 bars		**4 bars of 12 mm = 452 mm²**	IS 456:2000 cl. 26.3.1(a) (least distance between bars: the bar size, or 5 mm more than the aggregate size, 25 mm for 20 mm aggregate); Engine rule
Two hanging (top) bars Short, shallow beam	16 mm if the span is over 4.5 m or the beam deeper than 450 mm, else 12 mm		**2 bars of 12 mm = 226 mm²**	Engine rule: the bars that carry the stirrups through the span and run over both supports
Area of the two hanging bars	A = 2 × π φ² ÷ 4	2 × π × 12² ÷ 4	**226 mm²**	Engine rule
Extra top steel needed at the left support	max(hogging steel ; minimum) − hanging bars, not below 0	max(max(415; 138.8) − 226.2; 0)	**189 mm²**	Engine rule
Extra top steel needed at the right support	max(hogging steel ; minimum) − hanging bars, not below 0	max(max(604.5; 138.8) − 226.2; 0)	**378 mm²**	Engine rule
Extra top bars at the left support Cut off one third of the clear span from the face of the support	in one layer, at least 1 bar, not smaller than the hanging bar		**2 bars of 12 mm = 226 mm²**	Engine rule
Extra top bars at the right support Cut off one third of the clear span from the face of the support	in one layer, at least 1 bar, not smaller than the hanging bar		**4 bars of 12 mm = 452 mm²**	Engine rule
Top steel provided at the left support	A = hanging bars + extra bars	226.2 + 226.2	**452 mm²**	Engine rule
Top steel provided at the right support	A = hanging bars + extra bars	226.2 + 452.4	**679 mm²**	Engine rule
Moment of resistance of the top steel, left support	Mu = 0.87 fy Ast (d − 0.42 xu), xu = 0.87 fy Ast ÷ (0.36 fck b), xu not over 0.46 d	0.87 × 500 × 452.4 × (355 − 0.42 × min(0.87 × 500 × 452.4 ÷ (0.36 × 20 × 230); 0.46 × 355)) ÷ 10^6	**60.04 kN·m**	IS 456:2000 Annex G, cl. G-1.1
Moment of resistance of the top steel, right support	Mu = 0.87 fy Ast (d − 0.42 xu), xu = 0.87 fy Ast ÷ (0.36 fck b), xu not over 0.46 d	0.87 × 500 × 678.58 × (355 − 0.42 × min(0.87 × 500 × 678.58 ÷ (0.36 × 20 × 230); 0.46 × 355)) ÷ 10^6	**84.54 kN·m**	IS 456:2000 Annex G, cl. G-1.1
Moment of resistance of the bottom steel	Mu = 0.87 fy Ast (d − 0.42 xu), xu = 0.87 fy Ast ÷ (0.36 fck b), xu not over 0.46 d	0.87 × 500 × 452.4 × (355 − 0.42 × min(0.87 × 500 × 452.4 ÷ (0.36 × 20 × 230); 0.46 × 355)) ÷ 10^6	**60.04 kN·m**	IS 456:2000 Annex G, cl. G-1.1

The moments of resistance of the steel provided are used for the capacity-based shear below and for the strong-column weak-beam check of the columns (Section 7).

Beam on the outer wall line: shear and stirrups

STEP	FORMULA	WORKING	RESULT	SOURCE
Shear from the gravity loads Continuous beam: 10 % above wL/2 (0.55 wL at an interior support). Table 13 gives 0.6 wL on the outer side of the first interior support; the model uses 0.55	Vg = (wdv + ws + wlv) × Lclear ÷ 2 × kv	(16.733 + 1.4375 + 2.0758) × 3.9268 ÷ 2 × 1.1	**43.73 kN**	Engine rule; IS 456:2000 Table 13 for the support shear coefficients
Shear from the lateral moments	VE = (MEL + MER) ÷ Lclear	(14.93 + 14.93) ÷ 3.927	**7.60 kN**	Engine rule
Design shear force	Vu = max(1.5 Vg ; 1.2 (Vg + VE))	max(1.5 × 43.726; 1.2 × (43.726 + 7.6049))	**65.59 kN**	IS 456:2000 Table 18; IS 1893 (Part 1):2002 cl. 6.3.1.2

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Nominal shear stress	τv = Vu ÷ (b d)	65.59 × 1000 ÷ (230 × 355)	**0.803 N/mm²**	IS 456:2000 cl. 40.1
Maximum shear stress allowed for the grade The section is large enough in shear			**2.8 N/mm²**	IS 456:2000 Table 20
Tension steel percentage at the support The larger of the two support steels is used at both ends	pt = 100 × larger top steel ÷ (b d)	100 × max(452.4; 678.6) ÷ (230 × 355)	**0.831**	IS 456:2000 cl. 40.2.1, Table 19
Shear strength of the concrete pt is kept between 0.15 % and 3 %	τc = 0.85 √(0.8 fck) (√(1 + 5β) − 1) ÷ (6β), β = 0.8 fck ÷ (6.89 pt), not below 1	0.85 × √(0.8 × 20) × (√(1 + 5 × β) − 1) ÷ (6 × β), β = max(1; 0.8 × 20 ÷ (6.89 × 0.831))	**0.582 N/mm²**	IS 456:2000 Table 19: the formula of the code commentary (SP 24) which the table is made from
Stirrup size	8, 10, 12 mm tried in turn, the first whose end spacing is not under 100 mm		**8 mm, 2-legged (sizes tried: 8)**	Engine rule; IS 13920:1993 cl. 6.3.2 asks for 6 mm, or 8 mm where the clear span is over 5 m; 8 mm at least is the model's rule
Area of the two legs of a stirrup	Asv = 2 × π φ² ÷ 4	2 × π × 8² ÷ 4	**100.5 mm²**	Engine rule
Spacing for the minimum shear steel	s = Asv × 0.87 fy ÷ (0.4 b)	100.53 × 0.87 × 415 ÷ (0.4 × 230)	**395 mm**	IS 456:2000 cl. 26.5.1.6
Largest spacing allowed	s = min(0.75 d ; 300 mm)	min(0.75 × 355; 300)	**266 mm**	IS 456:2000 cl. 26.5.1.5
Spacing in the middle of the span, before the ductile rule	s = largest multiple of 25 mm not over min(smax ; smin steel), not under 75 mm	max(75; floor(min(266.3; 394.5) ÷ 25) × 25)	**250 mm**	Engine rule: spacings are rounded down to 25 mm
Shear from the gravity loads, without the 10 % allowance	Vg = (wdv + ws + wlv) × Lclear ÷ 2	(16.73 + 1.438 + 2.076) × 3.927 ÷ 2	**39.75 kN**	IS 13920:1993 cl. 6.3.3
Design shear from the moments of resistance The beam is made strong enough in shear to yield in bending first. The model takes the left top steel with the bottom steel for the one sway direction	Ve = max(Vu ; 1.2 Vg + 1.4 (Mhog,left + Msag) ÷ Lclear)	max(65.59; 1.2 × 39.75 + 1.4 × (60.04 + 60.04) ÷ 3.927)	**90.51 kN**	IS 13920:1993 cl. 6.3.3
Spacing needed for the shear	s = 0.87 fy Asv d ÷ Ve	0.87 × 415 × 100.5 × 355 ÷ (90.51 × 1000)	**142 mm**	IS 456:2000 cl. 40.4(a)
Spacing limit in the closely spaced zone	s = max(100 ; min(d ÷ 4 ; 8 × smallest main bar))	max(100; min(355 ÷ 4; 8 × 12))	**100.0 mm**	IS 13920:1993 cl. 6.3.5
Stirrup spacing at the ends	s = largest multiple of 25 mm not over min(shear ; rule), not under 100 mm	floor(min(142.4; 100) ÷ 25) × 25	**100 mm**	IS 13920:1993 cl. 6.3.5; Engine rule
Stirrup spacing elsewhere	s = max(100 ; multiple of 25 mm not over min(d ÷ 2 ; mid-span spacing))	max(100; floor(min(355 ÷ 2; 250) ÷ 25) × 25)	**175 mm**	IS 13920:1993 cl. 6.3.5 (d ÷ 2 outside the closely spaced zone); Engine rule
Length of the closely spaced zone at each end The first stirrup is 50 mm from the face of the support	z = 2 d	2 × 355	**710 mm**	IS 13920:1993 cl. 6.3.5
Number of stirrups in the span	n = 2 × (floor((z − 50) ÷ send) + 1) + (ceil((Lclear − 2 z) ÷ smid) − 1)	2 × (floor((min(710; 1,963) − 50) ÷ 100) + 1) + max(0; ceil((3,927 − 2 × min(710; 1,963)) ÷ 175) − 1)	**28**	Engine rule

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Cut length of one stirrup	Ls = 2 (A + E) + 12 φ + 2 × tail extra	2 × (180 + 350) + 12 × 8 + 2 × max(0; 75 − 10 × 8)	**1,156 mm**	Engine rule: 135° hooks with 10 φ tails, 75 mm at least (IS 13920:1993 cl. 6.3.1 for ductile hooks); A and E are the outside size of the stirrup (cover 25 mm each side)

Beam on the outer wall line: bar lengths and steel weight

Bars are measured to the next 25 mm, weighed by diameter (IS 1786), and this is the weight the quantities of the report are built from.

STEP	FORMULA	WORKING	RESULT	SOURCE
Cut length of a bottom bar Anchorage: at an outer column the bar goes to the far face less 40 mm cover and bends down 9 φ; at an inner column it runs to the middle of the column. Outer column at the left	L = Lclear + anchorage at each end	3,927 + 368 + 150	**4,445 mm**	Engine rule; IS 456:2000 cl. 26.2
Cut length of a hanging bar	L = Lclear + anchorage at each end	3,927 + 368 + 150	**4,445 mm**	Engine rule
Weight of the bottom bars	W = n × L (rounded up to 25 mm) × φ² ÷ 162.2	4 × 4,450 ÷ 1000 × 12² ÷ 162.2	**15.80 kg**	IS 1786:2008: mass per metre = φ² ÷ 162.2; IS 2502 cl. 5.1.1: lengths up to the next 25 mm
Weight of the hanging bars	W = 2 × L × φ² ÷ 162.2	2 × 4,450 ÷ 1000 × 12² ÷ 162.2	**7.90 kg**	IS 1786:2008; IS 2502 cl. 5.1.1
Cut length of an extra top bar, left support The extra top steel is carried one third of the clear span into the span: a planning rule of the model, not a curtailment drawing	L = Lclear ÷ 3 + anchorage	1,309 + 368	**1,677 mm**	Engine rule
Weight of the extra top bars, left support	W = n × L × φ² ÷ 162.2	2 × 1,700 ÷ 1000 × 12² ÷ 162.2	**3.02 kg**	IS 1786:2008; IS 2502 cl. 5.1.1
Cut length of an extra top bar, right support	L = Lclear ÷ 3 + anchorage	1,309 + 150	**1,459 mm**	Engine rule
Weight of the extra top bars, right support	W = n × L × φ² ÷ 162.2	4 × 1,475 ÷ 1000 × 12² ÷ 162.2	**5.24 kg**	IS 1786:2008; IS 2502 cl. 5.1.1
Weight of the stirrups	W = n × Ls (rounded up to 25 mm) × φ² ÷ 162.2	28 × 1,175 ÷ 1000 × 8² ÷ 162.2	**12.98 kg**	IS 1786:2008; IS 2502 cl. 5.1.1
Steel in this beam Before the correction of the modelled bays to the floor area you entered (Section 11, steel take-off)	sum of the weights above	44.94	**44.94 kg**	Engine rule

Inner beam: the beam and its size

STEP	FORMULA	WORKING	RESULT	SOURCE
Beam An inner beam. This is the beam that sets the size for its type. All beams of the type are in the table at the end of this section			**along the width, level 1, span 1 of 2 in its line**	Engine rule
Span, centre to centre			**4.23 m**	Section 3: the grid
Width of beam b Brick wall: 230 mm			**230 mm**	NirmanShastra assumption: the wall thickness, so that the beam does not show beyond the wall

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Column size assumed at each end of the beam The beams are designed before the columns, so the model assumes a column size by the number of floors it carries. The columns are then designed in Section 7			**300 mm**	Engine rule: estimated size
Clear span	Lclear = L – (cl + cr) ÷ 2	4.227 – (300 + 300) ÷ 2000	**3.927 m**	Engine rule
Slab thickness			**150 mm**	Section 3
Concrete grade			**20 N/mm²**	M20: Section 2
Steel strength fy (main bars)			**500 N/mm²**	IS 456:2000 cl. 5.6
Steel strength fy for stirrups For stirrups fy is not taken above 415 N/mm²			**415 N/mm²**	IS 456:2000 cl. 40.4
First trial depth	D = span ÷ 13, up to the next 25 mm, not under 300 mm	max(300; ceil(4.227 × 1000 ÷ 13 ÷ 25) × 25)	**350 mm**	Engine rule (starting point of the search; IS 456 cl. 23.2.1 span/depth ratios are checked below)
Depth search	The depth goes up in steps of 25 mm, from the first trial to at most 650 mm, until three checks pass together: the bending steel fits as a beam (not over-reinforced), the shear stress is under the Table 20 maximum, and the span to depth ratio is within the limit. Effective depth d = D – 45 mm (cover 25 mm, stirrup 8 mm, half a 25 mm bar, rounded).			IS 456:2000 cl. 23.2.1, cl. 40.2.3 and Table 20; Engine rule

Inner beam: depth search

Each row is one trial depth. The full moments and shears for the last row are worked below.

D (MM)	D (MM)	OWN WEIGHT (KN/M)	SHEAR STRESS (N/MM²)	LARGEST SHEAR STRESS ALLOWED (N/MM²)	SPAN ÷ D	ALLOWED	BENDING OK	SHEAR OK	DEFLECTION OK
350	305	1.150	0.91	2.80	13.9	22	No	Yes	Yes
375	330	1.294	0.85	2.80	12.8	22	No	Yes	Yes
400	355	1.438	0.79	2.80	11.9	22	Yes	Yes	Yes

Span ÷ d allowed: 22 for an end or single span and 26 for an interior span. These are the basic ratios of IS 456 cl. 23.2.1 (20 for a simply supported beam, 26 for a continuous one) with an assumed modification factor of about 1.1 for the steel stress; the factor is not computed from the steel provided, which is an assumption.

Inner beam: loads and gravity moments

STEP	FORMULA	WORKING	RESULT	SOURCE
Dead load for the moment: slab + wall (+ balcony)			**18.040 kN/m**	Section 4: equivalent uniform load
Imposed load for the moment			**5.492 kN/m**	Section 4
Dead load for the shear: slab + wall (+ balcony)			**14.353 kN/m**	Section 4
Imposed load for the shear			**4.152 kN/m**	Section 4
Own weight of the beam below the slab	ws = 25 × b × (D – t)	25 × 230 ÷ 1000 × (400 – 150) ÷ 1000	**1.438 kN/m**	IS 456:2000 cl. 19.2.1 (25 kN/m³)
Total dead load	wd = dead load + own weight	18.0398 + 1.4375	**19.477 kN/m**	Engine rule
Total service load	w = wd + wl	19.477 + 5.4921	**24.969 kN/m**	Engine rule

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Dead share of the load Used to take only the dead part of the gravity moment in the load cases where the imposed load is left out	rD = wd ÷ w	19.477 ÷ 24.969	**0.7800**	Engine rule
Moment coefficient at mid-span			**0.0833**	IS 456:2000 cl. 22.5.1, Table 12 (dead load with fixed imposed load): near the middle of an end span, 1/12
Moment coefficient at the left support			**0.0625**	NirmanShastra assumption: 1/16 at an outer support of a monolithic frame (IS 456 cl. 22.5.2 gives wL²/24 only where the end is built into masonry)
Moment coefficient at the right support			**0.1000**	IS 456:2000 cl. 22.5.1, Table 12 (dead load with fixed imposed load): support next to the end support, 1/10
Gravity moment at mid-span	Ms = c × w × L²	0.083333 × 24.96942 × 4.226815²	**37.18 kN·m**	IS 456:2000 cl. 22.5.1, Table 12 (dead load with fixed imposed load)
Gravity moment at the left support	Ms = c × w × L²	0.0625 × 24.969 × 4.2268²	**27.88 kN·m**	IS 456:2000 cl. 22.5.1, Table 12 (dead load with fixed imposed load)
Gravity moment at the right support	Ms = c × w × L²	0.1 × 24.969 × 4.2268²	**44.61 kN·m**	IS 456:2000 cl. 22.5.1, Table 12 (dead load with fixed imposed load)

The coefficients assume a continuous beam with equal spans. Each support of a real frame is only partly fixed, so the coefficients are an approximation (see the limits at the start of the sheet).

Inner beam: lateral moments at the ends

The lateral force (the larger of earthquake and wind, Section 5) bends the beams as well as the columns. The column moments below come from the portal method; the working is shown for the left end and the right end is the same method.

STEP	FORMULA	WORKING	RESULT	SOURCE
Shear of one frame, lateral load along y (left joint, column below) 4 frames in this direction on this storey	Vf = V ÷ number of frames	91.31 ÷ 4	**22.83 kN**	Engine rule: the storey shear is shared equally between the frames
Shear in the column (left joint, column below) An outer column carries half the shear of an inner column; 2 bays in the frame	Vc = Vf ÷ (2 nb)	22.828 ÷ (2 × 2)	**5.707 kN**	Portal method (standard approximate analysis)
Column end moment from the lateral load along y (left joint, column below)	M = Vc × h ÷ 2	5.7069 × 3 ÷ 2	**8.560 kN·m**	Portal method: contraflexure at mid-height
Joint moment at the left end	Mj = Mcol,below + a × Mcol,above	8.5604 + 1 × 6.3712	**14.932 kN·m**	Engine rule: the beam takes the sum of the column moments above and below the joint
Earthquake (or wind) moment at the left end of the beam The joint is on the outside of the frame: one beam	ME = Mj ÷ number of beams meeting at the joint	14.932 ÷ 1	**14.932 kN·m**	Engine rule: portal method, joint moment shared equally
Joint moment at the right end	Mj = Mcol,below + a × Mcol,above	17.121 + 1 × 12.742	**29.863 kN·m**	Engine rule: the beam takes the sum of the column moments above and below the joint

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Earthquake (or wind) moment at the right end of the beam	ME = Mj ÷ number of beams meeting at the joint	29.863 ÷ 2	**14.932 kN·m**	Engine rule: portal method, joint moment shared equally

Inner beam: design moments

Hogging is tension on top (at the supports), sagging is tension at the bottom. Each figure is the largest from the load combinations of Section 4.

STEP	FORMULA	WORKING	RESULT	SOURCE
Design hogging moment at the left support	Mu = max(1.5 Ms ; 1.2 (Ms + ME) ; 1.5 (rD Ms + ME))	max(1.5 × 27.881; 1.2 × (27.881 + 14.932); 1.5 × (0.78 × 27.881 + 14.932))	**55.02 kN·m**	IS 456:2000 Table 18; IS 1893 (Part 1):2002 cl. 6.3.1.2
Design hogging moment at the right support	Mu = max(1.5 Ms ; 1.2 (Ms + ME) ; 1.5 (rD Ms + ME))	max(1.5 × 44.61; 1.2 × (44.61 + 14.93); 1.5 × (0.78 × 44.61 + 14.93))	**74.59 kN·m**	IS 456:2000 Table 18; IS 1893 (Part 1):2002 cl. 6.3.1.2
Sagging moment at the left support (reversal)	Mu = max(0 ; 1.5 ME − 0.9 rD Ms)	max(0; 1.5 × 14.93 − 0.9 × 0.78 × 27.88)	**2.82 kN·m**	IS 456:2000 Table 18; IS 1893 (Part 1):2002 cl. 6.3.1.2 (0.9 DL + 1.5 EL)
Sagging moment at the right support (reversal)	Mu = max(0 ; 1.5 ME − 0.9 rD Ms)	max(0; 1.5 × 14.93 − 0.9 × 0.78 × 44.61)	**0.00 kN·m**	IS 456:2000 Table 18; IS 1893 (Part 1):2002 cl. 6.3.1.2 (0.9 DL + 1.5 EL)
Sagging moment at the left support, ductile rule At the face of a joint the bottom steel must be at least half the top steel	Mu = max(above ; 0.5 × hogging)	max(2.823; 0.5 × 55.02)	**27.51 kN·m**	IS 13920:1993 cl. 6.2.3
Sagging moment at the right support, ductile rule	Mu = max(above ; 0.5 × hogging)	max(0; 0.5 × 74.59)	**37.30 kN·m**	IS 13920:1993 cl. 6.2.3
Design sagging moment at mid-span	Mu = 1.5 Ms	1.5 × 37.175	**55.76 kN·m**	IS 456:2000 Table 18 (1.5 (DL + LL))

Inner beam: steel required for bending

STEP	FORMULA	WORKING	RESULT	SOURCE
Limiting moment of resistance of the section xu,max/d = 0.46 for Fe 500 (IS 456 cl. 38.1); a larger moment needs compression steel	Mu,lim = 0.36 fck b (xu,max/d) d² (1 − 0.42 xu,max/d)	0.36 × 20 × 230 × 0.46 × 355² × (1 − 0.42 × 0.46) ÷ 10^6	**77.45 kN·m**	IS 456:2000 Annex G, cl. G-1.1(c)
Steel for mid-span sagging	Ast = (0.5 fck ÷ fy) (1 − √(1 − 4.6 Mu ÷ (fck b d²))) b d	(0.5 × 20 ÷ 500) × (1 − √(1 − 4.6 × 55.76 × 10^6 ÷ (20 × 230 × 355²))) × 230 × 355	**414 mm²**	IS 456:2000 Annex G, cl. G-1.1(b)
Steel for hogging at the left support	Ast = (0.5 fck ÷ fy) (1 − √(1 − 4.6 Mu ÷ (fck b d²))) b d	(0.5 × 20 ÷ 500) × (1 − √(1 − 4.6 × 55.02 × 10^6 ÷ (20 × 230 × 355²))) × 230 × 355	**407 mm²**	IS 456:2000 Annex G, cl. G-1.1(b)
Steel for hogging at the right support	Ast = (0.5 fck ÷ fy) (1 − √(1 − 4.6 Mu ÷ (fck b d²))) b d	(0.5 × 20 ÷ 500) × (1 − √(1 − 4.6 × 74.59 × 10^6 ÷ (20 × 230 × 355²))) × 230 × 355	**590 mm²**	IS 456:2000 Annex G, cl. G-1.1(b)
Steel for sagging at the left support	Ast = (0.5 fck ÷ fy) (1 − √(1 − 4.6 Mu ÷ (fck b d²))) b d	(0.5 × 20 ÷ 500) × (1 − √(1 − 4.6 × 27.51 × 10^6 ÷ (20 × 230 × 355²))) × 230 × 355	**189 mm²**	IS 456:2000 Annex G, cl. G-1.1(b)
Steel for sagging at the right support	Ast = (0.5 fck ÷ fy) (1 − √(1 − 4.6 Mu ÷ (fck b d²))) b d	(0.5 × 20 ÷ 500) × (1 − √(1 − 4.6 × 37.3 × 10^6 ÷ (20 × 230 × 355²))) × 230 × 355	**263 mm²**	IS 456:2000 Annex G, cl. G-1.1(b)
Minimum tension steel	Ast,min = 0.85 b d ÷ fy	0.85 × 230 × 355 ÷ 500	**139 mm²**	IS 456:2000 cl. 26.5.1.1(a)

These are areas of steel in mm²; the bars chosen to provide them follow.

Inner beam: bars chosen

STEP	FORMULA	WORKING	RESULT	SOURCE

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Bottom steel required	max(mid-span ; sagging at supports ; minimum)	max(413.7; 138.8; 189.2; 262.8)	**414 mm²**	Engine rule
Bottom bars chosen A layer of a 230 mm beam holds at most 4 bars of 12 mm (clear spacing not under the larger of the bar size and 25 mm, cover 25 mm, stirrup 8 mm; site practice limits it to 4 bars)	smallest size from 12, 16, 20, 25, 32 mm that fits in one layer; at least 2 bars		**4 bars of 12 mm = 452 mm²**	IS 456:2000 cl. 26.3.1(a) (least distance between bars: the bar size, or 5 mm more than the aggregate size, 25 mm for 20 mm aggregate); Engine rule
Two hanging (top) bars Short, shallow beam	16 mm if the span is over 4.5 m or the beam deeper than 450 mm, else 12 mm		**2 bars of 12 mm = 226 mm²**	Engine rule: the bars that carry the stirrups through the span and run over both supports
Area of the two hanging bars	A = 2 × π φ² ÷ 4	2 × π × 12² ÷ 4	**226 mm²**	Engine rule
Extra top steel needed at the left support	max(hogging steel ; minimum) − hanging bars, not below 0	max(max(407.3; 138.8) − 226.2; 0)	**181 mm²**	Engine rule
Extra top steel needed at the right support	max(hogging steel ; minimum) − hanging bars, not below 0	max(max(589.8; 138.8) − 226.2; 0)	**364 mm²**	Engine rule
Extra top bars at the left support Cut off one third of the clear span from the face of the support	in one layer, at least 1 bar, not smaller than the hanging bar		**2 bars of 12 mm = 226 mm²**	Engine rule
Extra top bars at the right support Cut off one third of the clear span from the face of the support	in one layer, at least 1 bar, not smaller than the hanging bar		**4 bars of 12 mm = 452 mm²**	Engine rule
Top steel provided at the left support	A = hanging bars + extra bars	226.2 + 226.2	**452 mm²**	Engine rule
Top steel provided at the right support	A = hanging bars + extra bars	226.2 + 452.4	**679 mm²**	Engine rule
Moment of resistance of the top steel, left support	Mu = 0.87 fy Ast (d − 0.42 xu), xu = 0.87 fy Ast ÷ (0.36 fck b), xu not over 0.46 d	0.87 × 500 × 452.4 × (355 − 0.42 × min(0.87 × 500 × 452.4 ÷ (0.36 × 20 × 230); 0.46 × 355)) ÷ 10^6	**60.04 kN·m**	IS 456:2000 Annex G, cl. G-1.1
Moment of resistance of the top steel, right support	Mu = 0.87 fy Ast (d − 0.42 xu), xu = 0.87 fy Ast ÷ (0.36 fck b), xu not over 0.46 d	0.87 × 500 × 678.58 × (355 − 0.42 × min(0.87 × 500 × 678.58 ÷ (0.36 × 20 × 230); 0.46 × 355)) ÷ 10^6	**84.54 kN·m**	IS 456:2000 Annex G, cl. G-1.1
Moment of resistance of the bottom steel	Mu = 0.87 fy Ast (d − 0.42 xu), xu = 0.87 fy Ast ÷ (0.36 fck b), xu not over 0.46 d	0.87 × 500 × 452.4 × (355 − 0.42 × min(0.87 × 500 × 452.4 ÷ (0.36 × 20 × 230); 0.46 × 355)) ÷ 10^6	**60.04 kN·m**	IS 456:2000 Annex G, cl. G-1.1

The moments of resistance of the steel provided are used for the capacity-based shear below and for the strong-column weak-beam check of the columns (Section 7).

Inner beam: shear and stirrups

STEP	FORMULA	WORKING	RESULT	SOURCE
Shear from the gravity loads Continuous beam: 10 % above wL/2 (0.55 wL at an interior support). Table 13 gives 0.6 wL on the outer side of the first interior support; the model uses 0.55	Vg = (wdv + ws + wlv) × Lclear ÷ 2 × kv	(14.35 + 1.438 + 4.152) × 3.927 ÷ 2 × 1.1	**43.07 kN**	Engine rule; IS 456:2000 Table 13 for the support shear coefficients
Shear from the lateral moments	VE = (MEL + MER) ÷ Lclear	(14.93 + 14.93) ÷ 3.927	**7.60 kN**	Engine rule
Design shear force	Vu = max(1.5 Vg ; 1.2 (Vg + VE))	max(1.5 × 43.07; 1.2 × (43.07 + 7.605))	**64.61 kN**	IS 456:2000 Table 18; IS 1893 (Part 1):2002 cl. 6.3.1.2

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Nominal shear stress	τv = Vu ÷ (b d)	64.61 × 1000 ÷ (230 × 355)	**0.791 N/mm²**	IS 456:2000 cl. 40.1
Maximum shear stress allowed for the grade The section is large enough in shear			**2.8 N/mm²**	IS 456:2000 Table 20
Tension steel percentage at the support The larger of the two support steels is used at both ends	pt = 100 × larger top steel ÷ (b d)	100 × max(452.4; 678.6) ÷ (230 × 355)	**0.831**	IS 456:2000 cl. 40.2.1, Table 19
Shear strength of the concrete pt is kept between 0.15 % and 3 %	τc = 0.85 √(0.8 fck) (√(1 + 5β) − 1) ÷ (6β), β = 0.8 fck ÷ (6.89 pt), not below 1	0.85 × √(0.8 × 20) × (√(1 + 5 × β) − 1) ÷ (6 × β), β = max(1; 0.8 × 20 ÷ (6.89 × 0.831))	**0.582 N/mm²**	IS 456:2000 Table 19: the formula of the code commentary (SP 24) which the table is made from
Stirrup size	8, 10, 12 mm tried in turn, the first whose end spacing is not under 100 mm		**8 mm, 2-legged (sizes tried: 8)**	Engine rule; IS 13920:1993 cl. 6.3.2 asks for 6 mm, or 8 mm where the clear span is over 5 m; 8 mm at least is the model's rule
Area of the two legs of a stirrup	Asv = 2 × π φ² ÷ 4	2 × π × 8² ÷ 4	**100.5 mm²**	Engine rule
Spacing for the minimum shear steel	s = Asv × 0.87 fy ÷ (0.4 b)	100.53 × 0.87 × 415 ÷ (0.4 × 230)	**395 mm**	IS 456:2000 cl. 26.5.1.6
Largest spacing allowed	s = min(0.75 d ; 300 mm)	min(0.75 × 355; 300)	**266 mm**	IS 456:2000 cl. 26.5.1.5
Spacing in the middle of the span, before the ductile rule	s = largest multiple of 25 mm not over min(smax ; smin steel), not under 75 mm	max(75; floor(min(266.3; 394.5) ÷ 25) × 25)	**250 mm**	Engine rule: spacings are rounded down to 25 mm
Shear from the gravity loads, without the 10 % allowance	Vg = (wdv + ws + wlv) × Lclear ÷ 2	(14.3535 + 1.4375 + 4.15167) × 3.92682 ÷ 2	**39.16 kN**	IS 13920:1993 cl. 6.3.3
Design shear from the moments of resistance The beam is made strong enough in shear to yield in bending first. The model takes the left top steel with the bottom steel for the one sway direction	Ve = max(Vu ; 1.2 Vg + 1.4 (Mhog,left + Msag) ÷ Lclear)	max(64.61; 1.2 × 39.16 + 1.4 × (60.04 + 60.04) ÷ 3.927)	**89.80 kN**	IS 13920:1993 cl. 6.3.3
Spacing needed for the shear	s = 0.87 fy Asv d ÷ Ve	0.87 × 415 × 100.5 × 355 ÷ (89.8 × 1000)	**143 mm**	IS 456:2000 cl. 40.4(a)
Spacing limit in the closely spaced zone	s = max(100 ; min(d ÷ 4 ; 8 × smallest main bar))	max(100; min(355 ÷ 4; 8 × 12))	**100.0 mm**	IS 13920:1993 cl. 6.3.5
Stirrup spacing at the ends	s = largest multiple of 25 mm not over min(shear ; rule), not under 100 mm	floor(min(143.5; 100) ÷ 25) × 25	**100 mm**	IS 13920:1993 cl. 6.3.5; Engine rule
Stirrup spacing elsewhere	s = max(100 ; multiple of 25 mm not over min(d ÷ 2 ; mid-span spacing))	max(100; floor(min(355 ÷ 2; 250) ÷ 25) × 25)	**175 mm**	IS 13920:1993 cl. 6.3.5 (d ÷ 2 outside the closely spaced zone); Engine rule
Length of the closely spaced zone at each end The first stirrup is 50 mm from the face of the support	z = 2 d	2 × 355	**710 mm**	IS 13920:1993 cl. 6.3.5
Number of stirrups in the span	n = 2 × (floor((z − 50) ÷ send) + 1) + (ceil((Lclear − 2 z) ÷ smid) − 1)	2 × (floor((min(710; 1,963) − 50) ÷ 100) + 1) + max(0; ceil((3,927 − 2 × min(710; 1,963)) ÷ 175) − 1)	**28**	Engine rule

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Cut length of one stirrup	Ls = 2 (A + E) + 12 φ + 2 × tail extra	2 × (180 + 350) + 12 × 8 + 2 × max(0; 75 − 10 × 8)	**1,156 mm**	Engine rule: 135° hooks with 10 φ tails, 75 mm at least (IS 13920:1993 cl. 6.3.1 for ductile hooks); A and E are the outside size of the stirrup (cover 25 mm each side)

Inner beam: bar lengths and steel weight

Bars are measured to the next 25 mm, weighed by diameter (IS 1786), and this is the weight the quantities of the report are built from.

STEP	FORMULA	WORKING	RESULT	SOURCE
Cut length of a bottom bar Anchorage: at an outer column the bar goes to the far face less 40 mm cover and bends down 9 φ; at an inner column it runs to the middle of the column. Outer column at the left	L = Lclear + anchorage at each end	3,927 + 368 + 150	**4,445 mm**	Engine rule; IS 456:2000 cl. 26.2
Cut length of a hanging bar	L = Lclear + anchorage at each end	3,927 + 368 + 150	**4,445 mm**	Engine rule
Weight of the bottom bars	W = n × L (rounded up to 25 mm) × φ² ÷ 162.2	4 × 4,450 ÷ 1000 × 12² ÷ 162.2	**15.80 kg**	IS 1786:2008: mass per metre = φ² ÷ 162.2; IS 2502 cl. 5.1.1: lengths up to the next 25 mm
Weight of the hanging bars	W = 2 × L × φ² ÷ 162.2	2 × 4,450 ÷ 1000 × 12² ÷ 162.2	**7.90 kg**	IS 1786:2008; IS 2502 cl. 5.1.1
Cut length of an extra top bar, left support The extra top steel is carried one third of the clear span into the span: a planning rule of the model, not a curtailment drawing	L = Lclear ÷ 3 + anchorage	1,309 + 368	**1,677 mm**	Engine rule
Weight of the extra top bars, left support	W = n × L × φ² ÷ 162.2	2 × 1,700 ÷ 1000 × 12² ÷ 162.2	**3.02 kg**	IS 1786:2008; IS 2502 cl. 5.1.1
Cut length of an extra top bar, right support	L = Lclear ÷ 3 + anchorage	1,309 + 150	**1,459 mm**	Engine rule
Weight of the extra top bars, right support	W = n × L × φ² ÷ 162.2	4 × 1,475 ÷ 1000 × 12² ÷ 162.2	**5.24 kg**	IS 1786:2008; IS 2502 cl. 5.1.1
Weight of the stirrups	W = n × Ls (rounded up to 25 mm) × φ² ÷ 162.2	28 × 1,175 ÷ 1000 × 8² ÷ 162.2	**12.98 kg**	IS 1786:2008; IS 2502 cl. 5.1.1
Steel in this beam Before the correction of the modelled bays to the floor area you entered (Section 11, steel take-off)	sum of the weights above	44.94	**44.94 kg**	Engine rule

Beam schedule: every distinct beam

Beams with the same level, position, depth, bars and stirrups are one row. The span and the moments are those of the beam in the row with the largest moment. The rows agree with the beam schedule of the report.

LEVEL	POSITION	NUMBER	SIZE B × D (MM)	SPAN (M)	LARGEST HOGGING MU (KN·M)	MID-SPAN MU (KN·M)	SHEAR VU (KN)	BARS	STIRRUPS DIA @ END/MID (MM)
Level 1	Outer wall line	4	230 × 400	4.23	55.9	50.8	65.6	bottom 4-12, top 2-12 + 4-12	8 @ 100/175
Level 1	Outer wall line	2	230 × 375	3.66	58.2	27.0	53.2	bottom 2-12, top 2-12 + 3-12	8 @ 100/150
Level 1	Outer wall line	4	230 × 350	3.66	43.7	35.8	52.8	bottom 3-12, top 2-12 + 3-12	8 @ 100/150

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Level 1	Inner	4	230 × 400	4.23	55.0	55.8	64.6	bottom 4-12, top 2-12 + 4-12	8 @ 100/175
Level 1	Inner	2	230 × 350	3.66	41.9	37.6	49.5	bottom 3-12, top 2-12 + 2-12	8 @ 100/150
Level 1	Inner	1	230 × 350	3.66	55.2	28.2	49.5	bottom 3-12, top 2-12 + 3-12	8 @ 100/150
Roof	Outer wall line	4	230 × 350	4.23	30.0	31.9	38.1	bottom 3-12, top 2-12 + 2-12	8 @ 100/150
Roof	Outer wall line	6	230 × 300	3.66	30.7	16.2	29.3	bottom 2-12, top 2-12 + 1-12	8 @ 100/125
Roof	Inner	4	230 × 375	4.23	39.3	48.9	54.6	bottom 4-12, top 2-12 + 3-12	8 @ 100/150
Roof	Inner	3	230 × 300	3.66	39.7	24.1	40.5	bottom 3-12, top 2-12 + 2-12	8 @ 100/125
Total		**34**							

Level 0 sits at the top of the lowest storey. The plinth beams at foundation level are not part of this table.

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7. Column design

Each column carries the loads of the floors above it and the moments of the beams and of the lateral force. The search tries the sections of the model's list from the smallest up and keeps the first that passes every load case. The heaviest column of the lowest storey is worked in full; the table at the end lists every storey and column type.

What the column design rests on

STEP	FORMULA	WORKING	RESULT	SOURCE
Concrete grade of the columns			**20 N/mm²**	M20: Section 2
Cover to the main bars			**40 mm**	IS 456:2000 cl. 26.4.2.1: not under 40 mm
Bar sizes tried Not more than 8 bars of 12 mm, 12 bars of 16 mm, 16 bars of 20 mm, 20 bars of 25 mm: few, larger bars for compaction			**12, 16, 20, 25 mm in counts of 4, 6, 8, 10, 12, 14, 16, 18, 20, 24**	Engine rule
Steel percentage The code allows up to 6 %; 4 % is the practical limit where bars are lapped			**0.8 % to 4 % of the gross section**	IS 456:2000 cl. 26.5.3.1
Sections tried Square sections and a list of rectangles (the longer side along either axis)			**44 sizes from 230 × 230 mm up to 700 × 700 mm, in order of area**	Engine rule
Smallest side by floors carried Never under 230 mm			**1 floor 230 mm; 2 floors 300 mm; 3 floors 350 mm; 4 or more 400 mm**	Engine rule (Build Reference lower bounds); IS 13920 cl. 7.1.2 asks for 200 mm at least
Column size over the storeys The size found for the lower storey of the pair is carried up when it also passes there			**The same section in every storey**	Engine rule
Check of the section			**Biaxial interaction (cl. 39.6) for seven load cases, with the minimum eccentricity, by strain compatibility**	IS 456:2000 cl. 39.5 and 39.6
Choice among the sections that pass The model weights these three by fixed ratios internal to it; no price is used or shown			**The least combination of concrete volume, formwork area and steel weight**	Engine rule

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Worked column: which column

STEP	FORMULA	WORKING	RESULT	SOURCE
Column The column of the lowest storey that sets the largest section. All columns are in the schedule at the end of this section			**Ground floor, grid position 2, 2, interior column**	Engine rule
Storey height			**3.00 m**	Section 3
Unsupported length used for the minimum eccentricity Storey height less 400 mm for the beam. The beam depth is not known when the column loads are made, so 400 mm is assumed			**2,600 mm**	IS 456:2000 cl. 25.4 (unsupported length)
Own weight of the column in this storey, at the estimated size The loads are made before the columns are designed, so every column is weighed as a square of 300 mm (the size by floors carried)	Wc = 25 × s² × hs	25 × (300 ÷ 1000)² × 3	**6.75 kN**	IS 456:2000 cl. 19.2.1; Engine rule

Worked column: load from the beams of its own storey

A beam passes its load to its two ends in the shares of IS 456 Table 13: 0.4 at an outer support, 0.6 at the first interior support on the outer side, 0.55 on its inner side and 0.5 elsewhere. A single span shares 0.5 and 0.5.

BEAM	SPAN (M)	SHARE TO THIS COLUMN	BEAM DEAD LOAD INCL. OWN WEIGHT (KN)	BEAM IMPOSED LOAD (KN)	DEAD TO COLUMN (KN)	IMPOSED TO COLUMN (KN)
x-beam before the column	3.66	0.60	51.9	13.4	31.1	8.1
x-beam after the column	3.66	0.55	51.9	13.4	28.5	7.4
y-beam before the column	4.23	0.60	66.7	17.5	40.0	10.5
y-beam after the column	4.23	0.60	66.7	17.5	40.0	10.5
Total					**139.7**	**36.5**

Shares: IS 456:2000 cl. 22.5.1, Table 13. The beam loads are the shear-equivalent loads of Section 4 times the span, with the beam's own weight added to the dead load.

Worked column: load down the stack of storeys

The loads are added from the roof down. The imposed load on a column is reduced by the number of floors it carries (Section 4).

STOREY	DEAD FROM BEAMS (KN)	IMPOSED FROM BEAMS (KN)	OWN WEIGHT (KN)	DEAD LOAD CARRIED (KN)	IMPOSED CARRIED, BEFORE REDUCTION (KN)	FLOORS CARRIED	REDUCTION OF IMPOSED	IMPOSED CARRIED (KN)
Floor 1	119.7	27.4	6.8	126.4	27.4	1	0 %	27.4
Ground floor	139.7	36.5	6.8	272.9	63.9	2	10 %	57.5

The beam reactions of the other storeys are the same working as the table above, taken from the model.

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Worked column: axial load

STEP	FORMULA	WORKING	RESULT	SOURCE
Dead load at the foot of the column, Pdl			**272.9 kN**	Total of the dead column above
Imposed load at the foot of the column, Pll	Pll = imposed carried × (1 − reduction)	63.86 × (1 − 0.1)	**57.5 kN**	IS 875 (Part 2):1987 cl. 3.2.1
Service load on the column	P = Pdl + Pll	272.9 + 57.47	**330.4 kN**	Engine rule
Factored axial load	Pu = 1.5 (Pdl + Pll)	1.5 × 330.4	**495.6 kN**	IS 456:2000 Table 18

Worked column: moments from the gravity loads

The beams pass the difference of their end moments to the columns at a joint. The model takes the larger of what the joint above and the joint below pass to this column.

STEP	FORMULA	WORKING	RESULT	SOURCE
Service end moment of the x-beam before the joint (joint above) w = dead + imposed load of the beam including its own weight, unfactored	M = c × w × L²	0.08333 × 22.4026 × 3.66324²	**25.05 kN·m**	IS 456:2000 cl. 22.5.1, Table 12 (dead load with fixed imposed load)
Service end moment of the x-beam after the joint (joint above) w = dead + imposed load of the beam including its own weight, unfactored	M = c × w × L²	0.1 × 22.4 × 3.663²	**30.06 kN·m**	IS 456:2000 cl. 22.5.1, Table 12 (dead load with fixed imposed load)
Unbalanced moment about the y axis (joint above)	Mu = |M1 − M2|	|25.05 − 30.06|	**5.01 kN·m**	Engine rule: the difference of the beam end moments is passed to the columns
Service end moment of the y-beam before the joint (joint above) w = dead + imposed load of the beam including its own weight, unfactored	M = c × w × L²	0.1 × 24.969 × 4.2268²	**44.61 kN·m**	IS 456:2000 cl. 22.5.1, Table 12 (dead load with fixed imposed load)
Service end moment of the y-beam after the joint (joint above) w = dead + imposed load of the beam including its own weight, unfactored	M = c × w × L²	0.1 × 24.969 × 4.2268²	**44.61 kN·m**	IS 456:2000 cl. 22.5.1, Table 12 (dead load with fixed imposed load)
Unbalanced moment about the x axis (joint above)	Mu = |M1 − M2|	|44.61 − 44.61|	**0.00 kN·m**	Engine rule: the difference of the beam end moments is passed to the columns
Share of the unbalanced moment taken by this column at the joint above			**0.50**	Engine rule: half where a column continues above the joint, all of it at the roof
Share at the joint below			**0.50**	Engine rule: half goes to the column below
Service moment from the gravity loads about x	Mgx = max(share above × Mx,above ; 0.5 × Mx,below)	max(0.5 × 0; 0.5 × 0)	**0.00 kN·m**	Engine rule
Service moment from the gravity loads about y	Mgy = max(share above × My,above ; 0.5 × My,below)	max(0.5 × 5.01; 0.5 × 0)	**2.51 kN·m**	Engine rule

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Worked column: moments from the earthquake or wind

The lateral load along y bends the column about its x axis, and the load along x about its y axis (Section 5 gives the storey shears).

STEP	FORMULA	WORKING	RESULT	SOURCE
Shear of one frame, lateral load along y (this column) 4 frames in this direction on this storey	Vf = V ÷ number of frames	91.31 ÷ 4	**22.83 kN**	Engine rule: the storey shear is shared equally between the frames
Shear in the column (this column) An inner column; 2 bays in the frame	Vc = Vf ÷ nb	22.828 ÷ 2	**11.414 kN**	Portal method (standard approximate analysis)
Column end moment from the lateral load along y (this column)	M = Vc × h ÷ 2	11.414 × 3 ÷ 2	**17.121 kN·m**	Portal method: contraflexure at mid-height
Shear of one frame, lateral load along x (this column) 3 frames in this direction on this storey	Vf = V ÷ number of frames	91.31 ÷ 3	**30.44 kN**	Engine rule: the storey shear is shared equally between the frames
Shear in the column (this column) An inner column; 3 bays in the frame	Vc = Vf ÷ nb	30.437 ÷ 3	**10.146 kN**	Portal method (standard approximate analysis)
Column end moment from the lateral load along x (this column)	M = Vc × h ÷ 2	10.1456 × 3 ÷ 2	**15.218 kN·m**	Portal method: contraflexure at mid-height

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Worked column: strong column - weak beam

In Zone III and above the columns at a joint must be stronger than the beams that meet in it, so that a hinge forms in the beams first. The model does this by adding the moment the column must carry as an extra load case. The comparison uses the beam moments of resistance worked in Section 6.

STEP	FORMULA	WORKING	RESULT	SOURCE
Dead share of the gravity moment			**0.75**	NirmanShastra assumption: the dead load is taken as 75 % of the gravity moment where the imposed load is left out
Share of the beam moments the column must carry The model asks the columns above and below a joint to carry 1.1 times the beam moments of resistance between them, half each: 1.1 ÷ 2 = 0.55			**0.55**	Engine rule: a strong-column weak-beam check with a factor of 1.1, which is the model's own value. IS 13920:1993 has no clause for it. A software help page gives 1.4 for IS 13920:2016 (cl. 7.2; the 2016 text was not read), so a column meant for the 2016 rule may need more moment capacity than this
Beam moments of resistance about the y axis (joint above)	ΣMb = max(Mhog,1 + Msag,2 ; Msag,1 + Mhog,2)	max(50.2 + 39.49; 39.49 + 60.53)	**100.02 kN·m**	Engine rule: the beam moments of resistance on opposite faces of the joint, of opposite sign, are added as IS 13920:1993 cl. 7.3.4 adds them for the column shear
Beam moments of resistance about the x axis (joint above)	ΣMb = max(Mhog,1 + Msag,2 ; Msag,1 + Mhog,2)	max(84.54 + 60.04; 60.04 + 84.54)	**144.58 kN·m**	Engine rule: the beam moments of resistance on opposite faces of the joint, of opposite sign, are added as IS 13920:1993 cl. 7.3.4 adds them for the column shear
Column moment required about x	Mreq = 0.55 × larger of the sums above and below	0.55 × max(144.58; 0)	**79.52 kN·m**	Engine rule: a strong-column weak-beam check with a factor of 1.1, which is the model's own value. IS 13920:1993 has no clause for it. A software help page gives 1.4 for IS 13920:2016 (cl. 7.2; the 2016 text was not read), so a column meant for the 2016 rule may need more moment capacity than this
Column moment required about y	Mreq = 0.55 × larger of the sums above and below	0.55 × max(100.02; 0)	**55.01 kN·m**	Engine rule: a strong-column weak-beam check with a factor of 1.1, which is the model's own value. IS 13920:1993 has no clause for it. A software help page gives 1.4 for IS 13920:2016 (cl. 7.2; the 2016 text was not read), so a column meant for the 2016 rule may need more moment capacity than this

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Worked column: the load cases

Each case is a column load that must be carried by the section. EL is the earthquake or wind. 100 % of the lateral force acts one way and 30 % the other (IS 1893 cl. 6.3.2; the model applies this to every column, which is on the safe side for a frame with its elements along two perpendicular axes). Moments are taken positive: the section is symmetrical, so the sign of the lateral load does not matter.

CASE	COMBINATION AND MOMENTS	PU (KN)	MX (KN·M)	MY (KN·M)
1	1.5 (DL + LL): Mx = 1.5 Mgx ; My = 1.5 Mgy	495.6	0.00	3.76

2	1.2 (DL + LL + EL along y, 30 % along x): Mx = 1.2 (Mgx + MEx) ; My = 1.2 (Mgy + 0.3 MEy)	396.5	20.54	8.48
3	1.2 (DL + LL + EL along x, 30 % along y): Mx = 1.2 (Mgx + 0.3 MEx) ; My = 1.2 (Mgy + MEy)	396.5	6.16	21.27
4	1.5 (DL + EL along y, 30 % along x): Mx = 1.5 (rD Mgx + MEx) ; My = 1.5 (rD Mgy + 0.3 MEy)	409.4	25.68	9.67
5	1.5 (DL + EL along x, 30 % along y): Mx = 1.5 (rD Mgx + 0.3 MEx) ; My = 1.5 (rD Mgy + MEy)	409.4	7.70	25.65
6	0.9 DL + 1.5 EL along y, 30 % along x: Mx = 1.5 MEx + 0.9 rD Mgx ; My = 0.45 MEy + 0.9 rD Mgy	245.6	25.68	8.54
7	0.9 DL + 1.5 EL along x, 30 % along y: Mx = 0.45 MEx + 0.9 rD Mgx ; My = 1.5 MEy + 0.9 rD Mgy	245.6	7.70	24.52
8	Strong column - weak beam, about x: Mx = Mreq	396.5	79.52	0.00
9	Strong column - weak beam, about y: My = Mreq	396.5	0.00	55.01

The axial load does not change with the lateral load. The extra column load and relief from the overturning of the building are not added (see the limits at the start of the sheet).

Worked column: the section

STEP	FORMULA	WORKING	RESULT	SOURCE
Concrete grade			**20 N/mm²**	M20: Section 2
Width b (along x) Chosen by the search: the sections of the model's list from the smallest up, the first that passes every load case (with the least weighted concrete, formwork and steel of those that do)			**300 mm**	Engine rule
Depth D (along y)			**350 mm**	Engine rule
Bars Bars are spread round the perimeter at even spacing			**4 bars of 20 mm: 2 along each face of width b and 2 along each face of depth D (corners counted in both)**	IS 456:2000 cl. 26.5.3
Area of longitudinal steel	Asc = n × π φ² ÷ 4	4 × π × 20² ÷ 4	**1,257 mm²**	Engine rule
Steel percentage	p = 100 Asc ÷ (b D)	100 × 1,257 ÷ (300 × 350)	**1.20 %**	IS 456:2000 cl. 26.5.3.1(a): not under 0.8 %; the model keeps it under 4 %
Distance from the face to the centre of a corner bar A 8 mm tie is assumed for placing the bars, even where a 10 mm tie is used with 25 mm bars	c = cover + tie + φ ÷ 2	40 + 8 + 20 ÷ 2	**58.0 mm**	IS 456:2000 cl. 26.4.2.1 (cover to columns 40 mm); Engine rule
Spacing of bars along a face of width b Clear gap 164.0 mm	s = (b − 2c) ÷ (nb − 1)	(300 − 2 × 58) ÷ (2 − 1)	**184.0 mm**	IS 456:2000 cl. 26.5.3.1(g): not over 300 mm along the face; clear gap not under the larger of the bar size and 25 mm (cl. 26.3.1)
Spacing of bars along a face of depth D Clear gap 214.0 mm	s = (D − 2c) ÷ (nd − 1)	(350 − 2 × 58) ÷ (2 − 1)	**234.0 mm**	IS 456:2000 cl. 26.5.3.1(g)
Minimum eccentricity over the depth D	emin = max(lu ÷ 500 + D ÷ 30 ; 20 mm)	max(2,600 ÷ 500 + 350 ÷ 30; 20)	**20.0 mm**	IS 456:2000 cl. 25.4

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Minimum eccentricity over the width b	emin = max(lu ÷ 500 + b ÷ 30 ; 20 mm)	max(2,600 ÷ 500 + 300 ÷ 30; 20)	**20.0 mm**	IS 456:2000 cl. 25.4
Slenderness	lu ÷ D = 7.4 and lu ÷ b = 8.7. IS 456 cl. 25.1.2 treats a column as short when both effective length ratios are under 12. The model uses the unsupported length as the effective length and adds no extra moment for slenderness.			IS 456:2000 cl. 25.1.2

Worked column: the biaxial check of every case

For each case: the moment used is the larger of the case moment and Pu × emin. Puz = 0.45 fck Ac + 0.75 fy Asc (cl. 39.6). Mux1 and Muy1 are the moments the section can carry about each axis alone at that axial load (strain compatibility, below). The check is (Mux ÷ Mux1)^n + (Muy ÷ Muy1)^n ≤ 1, with the exponent n = αn = 1 for Pu ÷ Puz up to 0.2, 2 from 0.8 and a straight line between (cl. 39.6).

CASE	PU (KN)	MX USED (KN·M)	MY USED (KN·M)	PUZ (KN)	PU ÷ PUZ	EXPONENT N	MUX1 (KN·M)	MUY1 (KN·M)	RATIO
1	495.6	9.91	9.91	1,404.9	0.353	1.255	94.97	76.62	0.136
2	396.5	20.54	8.48	1,404.9	0.282	1.137	101.55	81.60	0.239
3	396.5	7.93	21.27	1,404.9	0.282	1.137	101.55	81.60	0.272
4	409.4	25.68	9.67	1,404.9	0.291	1.152	100.69	81.01	0.293
5	409.4	8.19	25.65	1,404.9	0.291	1.152	100.69	81.01	0.321
6	245.6	25.68	8.54	1,404.9	0.175	1.000	93.82	75.48	0.387
7	245.6	7.70	24.52	1,404.9	0.175	1.000	93.82	75.48	0.407
8	396.5	79.52	7.93	1,404.9	0.282	1.137	101.55	81.60	0.828
9	396.5	7.93	55.01	1,404.9	0.282	1.137	101.55	81.60	0.694

A ratio of 1 or under passes. The section was chosen so that every case passes; the largest ratio is 0.828 (case 8: Strong column - weak beam, about x).

Worked column: strain compatibility, bending about x (worst case)

STEP	FORMULA	WORKING	RESULT	SOURCE
Worst case Strong column - weak beam, about x: Pu = 396.5 kN			**8**	Engine rule
Stress-strain curves	Concrete: parabola to a strain of 0.002 and flat to 0.0035, peak stress 0.446 fck = 8.92 N/mm². Steel: ES = 2,00,000 N/mm², stress limited to 0.87 fy = 435 N/mm² in tension and in compression (a flat top). The curve for cold-worked bars in IS 456 Fig. 23A rises more gently near yield, so the flat top gives a slightly higher bar stress than the code curve between about 0.0017 and 0.004 strain; the model does not use the sloping branch. The compression zone is divided into 48 strips, and a bar in the compression zone has the concrete it displaces taken off its stress.			IS 456:2000 cl. 38.1, Fig. 21 (concrete) and Fig. 23 (steel); NirmanShastra assumption for the flat top
Neutral-axis depth found for bending about x Measured from the compression face over the depth D = 350 mm	xu such that the axial force of concrete and steel equals Pu	182 found by halving the interval 40 times	**182.0 mm**	IS 456:2000 cl. 39.1 and 38.1 (sections stay plane; the strain limits of 39.1); Engine rule (solved by halving)
Force in the concrete (bending about x)	Cc = Σ stress × width × strip depth	3,94,396 ÷ 1000	**394.4 kN**	IS 456:2000 cl. 38.1
Net force in the steel (bending about x)	Cs = Σ bar stress × bar area	2,068 ÷ 1000	**2.1 kN**	IS 456:2000 cl. 38.1
Axial force of the section (bending about x)	P = Cc + Cs, equal to Pu	394.4 + 2.068	**396.5 kN**	IS 456:2000 cl. 39.5
Moment capacity about x	Mux1 = Σ force × lever arm about the centroid	10,15,51,767 ÷ 10^6	**101.55 kN·m**	IS 456:2000 cl. 39.5

BAR LEVEL, FROM THE COMPRESSION FACE (MM)	BARS AT THIS LEVEL	STRAIN (PER MILLE)	STRESS (N/MM²)	FORCE (KN)
58.0	2	2.385	426.1	267.7
292.0	2	-2.114	-422.8	-265.6

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Strain is positive in compression. The bars at one level share the same strain. The forces add to the axial load Pu = 396.5 kN.

Worked column: strain compatibility, bending about y (worst case)

STEP	FORMULA	WORKING	RESULT	SOURCE
Neutral-axis depth found for bending about y Measured from the compression face over the width b = 300 mm	xu such that the axial force of concrete and steel equals Pu	152.8 found by halving the interval 40 times	**152.8 mm**	IS 456:2000 cl. 39.1 and 38.1 (sections stay plane; the strain limits of 39.1); Engine rule (solved by halving)
Force in the concrete (bending about y)	Cc = Σ stress × width × strip depth	3,86,127 ÷ 1000	**386.1 kN**	IS 456:2000 cl. 38.1
Net force in the steel (bending about y)	Cs = Σ bar stress × bar area	10,337 ÷ 1000	**10.3 kN**	IS 456:2000 cl. 38.1
Axial force of the section (bending about y)	P = Cc + Cs, equal to Pu	386.13 + 10.337	**396.5 kN**	IS 456:2000 cl. 39.5
Moment capacity about y	Muy1 = Σ force × lever arm about the centroid	8,15,98,347 ÷ 10^6	**81.60 kN·m**	IS 456:2000 cl. 39.5

BAR LEVEL, FROM THE COMPRESSION FACE (MM)	BARS AT THIS LEVEL	STRAIN (PER MILLE)	STRESS (N/MM²)	FORCE (KN)
58.0	2	2.171	425.3	267.2
242.0	2	-2.044	-408.9	-256.9

Strain is positive in compression. The bars at one level share the same strain. The forces add to the axial load Pu = 396.5 kN.

Worked column: ties

The ties hold the main bars against buckling and, in a ductile column, confine the concrete near the joints.

STEP	FORMULA	WORKING	RESULT	SOURCE
Clear height of the column concrete in this storey, Lc			**4,350 mm**	Engine rule: storey height less the slab; the lowest storey also includes the part down to the footing
Tie diameter Main bars 20 mm	the size designed with the column: 8 mm, or 10 mm with 25 mm bars		**8 mm**	IS 13920:1993 cl. 7.3.1 for the rectangular hoop with 135° hooks; Engine rule for the size
Pitch limit of ties IS 456:2000 gives the least side, 16 × the smallest bar and 300 mm. The 48 × tie diameter limit is from the earlier edition (1978), as SP 34 repeats it; the model keeps it	s = min(least side ; 16 × smallest main bar ; 48 × tie ; 300)	min(300; 16 × 20; 48 × 8; 300)	**300 mm**	IS 456:2000 cl. 26.5.3.2(c)(1) for the least side, 16 × the smallest bar and 300 mm; SP 34:1987 section 7.2.6.1 for the 48 × tie diameter
Length of the closely tied zone at each end	lo = max(larger side ; Lc ÷ 6 ; 450 mm)	max(350; 4,350 ÷ 6; 450)	**725 mm**	IS 13920:1993 cl. 7.4.1
Tie spacing in the closely tied zone	s = min(100 ; max(75 ; one quarter of the least side, in whole 5 mm))	min(100; max(75; floor(300 ÷ 4 ÷ 5) × 5))	**75 mm**	IS 13920:1993 cl. 7.4.6
Tie spacing outside the closely tied zones	s = max(75 ; multiple of 25 mm not over min(half the least side ; pitch limit))	max(75; floor(min(300 ÷ 2; 300) ÷ 25) × 25)	**150 mm**	IS 13920:1993 cl. 7.3.3 (half the least side); Engine rule
Ties in the two closely tied zones	n = 2 × ceil(lo ÷ s)	2 × ceil(725 ÷ 75)	**20**	Engine rule
Ties between the zones	n = max(0 ; ceil((Lc − 2 lo) ÷ s) − 1)	max(0; ceil((4,350 − 2 × 725) ÷ 150) − 1)	**19**	Engine rule
Cut length of one tie A rectangular tie with its cut length is how the bars are bought and bent	Lt = 2 (A + E) + 12 φ + 2 × tail extra	2 × (220 + 270) + 12 × 8 + 2 × max(0; 75 − 10 × 8)	**1,076 mm**	Engine rule: A and E are the outside size of the tie (cover 40 mm each side), 135° hooks with 10 φ tails of at least 75 mm

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Cross-ties across the depth, at each tie level The code lets a bar go without its own tie when bars are not spaced more than 75 mm on either side of a tied bar. The model reads this as 75 mm clear and gives a cross-tie to any bar beyond. Counted from the bar spacing above			**0**	IS 456:2000 cl. 26.5.3.2(b)(1)
Cross-ties across the width, at each tie level			**0**	IS 456:2000 cl. 26.5.3.2(b)(1)

Worked column: confining steel check (not made by the model)

IS 13920 asks for a minimum area of the bar forming the hoop in the closely tied zone. The quantity model does not make this check, so it is worked here beside the model's tie size for the engineer who reads the sheet.

STEP	FORMULA	WORKING	RESULT	SOURCE
Area of the tie bar needed for confinement h = longer side of the hoop, measured to its outside (270 mm; the code caps it at 300 mm, cross-ties shorten it); Ak = area inside the hoop; fy of the hoop taken as 415 N/mm², the value the model uses for every stirrup and tie (IS 456 cl. 40.4). Amendment No. 2 of IS 13920:1993 admits Fe 500 and Fe 550 thermo-mechanically treated bars, and with fy = 500 the area needed would be about 17 % smaller	Ash = 0.18 s h (fck ÷ fy) (Ag ÷ Ak − 1)	0.18 × 75 × 270 × (20 ÷ 415) × (1,05,000 ÷ 59,400 − 1)	**134.9 mm²**	IS 13920:1993 cl. 7.4.8
Area of one tie bar	A = π φ² ÷ 4	π × 8² ÷ 4	**50.3 mm²**	Engine rule
Area of all the legs of the hoop and cross-ties in one direction The 1993 text defines Ash as the area of the bar forming the hoop, one bar. Designers commonly count every leg of the hoop and its cross-ties in the direction considered, which is the more favourable reading. Both readings are shown below. The side with more cross-ties is taken	A × (2 + cross-ties)	50.27 × (2 + 0)	**100.5 mm²**	IS 13920:1993 cl. 7.4.8
Confinement, reading 1: the one bar forming the hoop (the wording of the 1993 text) One bar gives 0.37 of the area asked for	one bar ≥ needed		**Not met**	IS 13920:1993 cl. 7.4.8
Confinement, reading 2: every leg of the hoop and its cross-ties counted Every leg counted gives 0.75 of the area asked for. The model chooses the tie size from its spacing rules and does not make this check. A structural engineer must give the confining ties of the drawings; the tie steel quantity here is for the tie size shown	all legs ≥ needed		**Not met**	IS 13920:1993 cl. 7.4.8

Column schedule: every storey and column type

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Columns of the same storey, type, section and bars are one row. The loads and the ratio are those of the column with the largest axial load in the row. A ratio of 1 or under passes the biaxial check.

STOREY	TYPE	NUMBER	SIZE B × D (MM)	BARS	STEEL %	TIES DIA @ END/MID (MM)	LARGEST PU (KN)	LARGEST RATIO	CASE THAT GOVERNS	LU ÷ LEAST SIDE
Ground floor	Corner	4	300 × 300	4-16	0.89	8 @ 75/150	164.8	0.808	1.5 (DL ± EL), EL along y + 30 % along x	8.7
Ground floor	Edge	2	300 × 350	4-20	1.20	8 @ 75/150	330.8	0.902	Strong column - weak beam, about x	8.7
Ground floor	Edge	4	350 × 300	8-12	0.86	8 @ 75/150	297.2	0.918	Strong column - weak beam, about y	8.7
Ground floor	Interior	2	300 × 350	4-20	1.20	8 @ 75/150	495.6	0.828	Strong column - weak beam, about x	8.7
Floor 1	Corner	4	300 × 300	8-12	1.01	8 @ 75/150	63.1	0.916	1.5 (DL ± EL), EL along y + 30 % along x	8.7
Floor 1	Edge	2	300 × 350	8-16	1.53	8 @ 75/150	131.6	0.906	Strong column - weak beam, about x	8.7
Floor 1	Edge	4	350 × 300	8-12	0.86	8 @ 75/150	119.6	0.980	Strong column - weak beam, about y	8.7
Floor 1	Interior	2	300 × 350	4-20	1.20	8 @ 75/150	230.7	0.954	Strong column - weak beam, about x	8.7
Total		**24**								

Storey 0 is the lowest storey of the frame. A ratio above 1 would mean the search reached the largest section on its list; the model then warns that a larger section or higher grade will be needed. lu ÷ least side is the slenderness measure of IS 456 cl. 25.1.2 (short when under 12).

Confining steel of IS 13920 cl. 7.4.8 for every column row (worked here, not made by the model)

The area of the hoop bar asked for in the closely tied zone, Ash = 0.18 s h (fck ÷ fy) (Ag ÷ Ak − 1), is worked for the representative column of each row of the schedule above, beside the area of the tie the model counts. Reading 1 compares it with the one bar that forms the hoop, as the 1993 text words it. Reading 2 counts every leg of the hoop and its cross-ties in the direction considered, as designers commonly do.

STOREY	TYPE	SIZE (MM)	TIE DIA @ SPACING (MM)	ASH NEEDED (MM²)	ONE BAR (MM²)	ALL LEGS (MM²)	ONE BAR	ALL LEGS
Ground floor	Corner	300 × 300	8 @ 75	123.0	50.3	100.5	Not met	Not met
Ground floor	Edge	300 × 350	8 @ 75	134.9	50.3	100.5	Not met	Not met
Ground floor	Edge	350 × 300	8 @ 75	134.9	50.3	150.8	Not met	Met
Ground floor	Interior	300 × 350	8 @ 75	134.9	50.3	100.5	Not met	Not met
Floor 1	Corner	300 × 300	8 @ 75	123.0	50.3	150.8	Not met	Met
Floor 1	Edge	300 × 350	8 @ 75	134.9	50.3	150.8	Not met	Met
Floor 1	Edge	350 × 300	8 @ 75	134.9	50.3	150.8	Not met	Met
Floor 1	Interior	300 × 350	8 @ 75	134.9	50.3	100.5	Not met	Not met

0 of 8 rows meet it by reading 1 and 4 of 8 by reading 2. The model does not make this check: it chooses the tie size from its spacing rules, and the tie steel quantity of the report is for that size. Where a row is not met, the signed drawings are likely to carry heavier ties than the model counts.

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8. Foundations and plinth beams

The foundation is a set of isolated footings, one under each ground-storey column, on the bearing capacity assumed for your ground class. One footing is worked in full below; the others follow the same steps and are listed in a schedule. Plinth beams tie the columns at the plinth.

How the foundation type was decided

The model first gives every ground-storey column the isolated footing it needs on 150 kN/m², unless the ground class asks for a raft outright. The footings are accepted only if they fit their bays and leave room between them.

STEP	FORMULA	WORKING	RESULT	SOURCE
Safe bearing capacity assumed Taken from Section 2			**150 kN/m²**	NirmanShastra assumption: by ground class
Ground class asks for a raft	set for steep slopes, black cotton soil and soft or marshy ground		**No**	NirmanShastra assumption: by ground class
Columns at the ground storey, each with a trial footing Every column is first given the isolated footing its load needs (the same design as the footing worked below)			**12**	Engine rule
Longest trial footing	Lf,max = largest Lf	largest Lf of the trial footings = 1.6	**1.60 m**	Engine rule
Widest trial footing	Bf,max = largest Bf	largest Bf of the trial footings = 1.55	**1.55 m**	Engine rule
Longest footing the bay can take	sx − 0.3	3.663 − 0.3	**3.36 m**	Engine rule: 0.3 m of the bay is kept clear between neighbouring footings
Widest footing the bay can take	sy − 0.3	4.227 − 0.3	**3.93 m**	Engine rule
A trial footing is larger than its bay	Lf,max > sx − 0.3 or Bf,max > sy − 0.3		**No**	Engine rule
Plan area covered by the trial footings	Σ Lf × Bf	sum of Lf × Bf over the 12 trial footings = 18.46	**18.46 m²**	Engine rule
Half of the plan of the frame	0.5 × L × W	0.5 × 10.99 × 8.454	**46.45 m²**	Engine rule: footings that cover more than half the plan are replaced by a raft
The footings cover more than half of the plan	Σ Lf × Bf > 0.5 L W		**No**	Engine rule
Foundation used These tests are the model's own planning rules, not a code check. A raft is the usual answer when footings would meet or overlap.	isolated footings unless one of the two tests above is met		**Isolated footings**	Engine rule

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Load on the footing

STEP	FORMULA	WORKING	RESULT	SOURCE
Footing worked The footing under the column with the largest factored load			**interior column at grid position (2, 2); factored load 496 kN**	Engine rule
Column section b × D b is the side along x, D the side along y			**300 × 350 mm**	Engine rule
Concrete grade of the footing fck = 25 N/mm²			**M25**	IS 456:2000 Table 5
Service load on the column (dead + imposed) From the load take-down of Section 7	P = Pdl + Pll	272.9 + 57.47	**330.4 kN**	IS 875 (Part 2):1987 cl. 3.2.1 for the reduction; Section 7
Factored load	Pu = 1.5 × P	1.5 × 330.4	**495.6 kN**	IS 456:2000 Table 18

Plan size

STEP	FORMULA	WORKING	RESULT	SOURCE
Plan area needed The 1.1 adds 10 % for the weight of the footing and the earth above it: a NirmanShastra planning allowance, not a code factor. The bearing capacity is an assumed value for the ground class.	A = 1.1 P ÷ sbc	1.1 × 330.4 ÷ 150	**2.423 m²**	IS 456:2000 cl. 34.1; IS 1904:1986: the soil pressure is kept within the bearing capacity
Side of a square footing	side = max(1.0 ; √A)	max(1; √2.423)	**1.557 m**	Engine rule: no footing narrower than 1.0 m
Difference of the column sides	(D – b) ÷ 1000	(350 – 300) ÷ 1000	**0.050 m**	Engine rule
Footing width Bf	Bf = side – (D – b) ÷ 2, rounded up to 50 mm, not under 1.0 m	ceil(max(1; 1.557 – 0.05 ÷ 2) ÷ 0.05) × 0.05	**1.55 m**	Engine rule
Footing length Lf The footing is longer on the side of the longer column face, so that it projects equally on all sides	Lf = Bf + (D – b), rounded up to 50 mm	ceil((1.55 + max(0; 0.05)) ÷ 0.05) × 0.05	**1.60 m**	Engine rule
Upward pressure under the factored load	qu = Pu ÷ (Lf × Bf)	495.6 ÷ (1.6 × 1.55)	**199.8 kN/m²**	IS 456:2000 cl. 34.2.3.1 and 34.2.3.2(a)

Search for the depth

The effective depth d starts at 225 mm and goes up in steps of 25 mm until one-way shear, punching shear and bending are all within their limits. 1 depths were tried.

D (MM)	ONE-WAY SHEAR STRESS, X / Y (N/MM²)	PUNCHING SHEAR STRESS (N/MM²)	MOMENT X / Y (KN·M)	RESULT
225	0.355 / 0.355 (≤ 0.395)	0.879 (≤ 1.250)	60.5 / 62.4 (≤ 235.6 / 243.2)	passes

The effective depth used in the search takes no cover off; 12 mm is taken off for the bending check only. The 0.3 % tension steel used for τc is a planning value (the actual steel is found later).

Tests at the depth found, d = 225 mm

STEP	FORMULA	WORKING	RESULT	SOURCE

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One-way shear force at d from the column face, along Lf The footing acting as a wide beam: critical section at the effective depth from the face of the column	V = qu × Bf × ((Lf − D) ÷ 2 − d)	199.8 × 1.55 × ((1.6 × 1000 − 350) ÷ 2000 − 225 ÷ 1000)	**123.9 kN**	IS 456:2000 cl. 34.2.4.1
Shear stress, along Lf	τv = V ÷ (Bf × d)	max(0; 123.9) × 1000 ÷ (1.55 × 1000 × 225)	**0.355 N/mm²**	IS 456:2000 cl. 34.2.4.1
One-way shear force at d from the column face, along Bf	V = qu × Lf × ((Bf − b) ÷ 2 − d)	199.8 × 1.6 × ((1.55 × 1000 − 300) ÷ 2000 − 225 ÷ 1000)	**127.9 kN**	IS 456:2000 cl. 34.2.4.1
Shear stress, along Bf	τv = V ÷ (Lf × d)	max(0; 127.9) × 1000 ÷ (1.6 × 1000 × 225)	**0.355 N/mm²**	IS 456:2000 cl. 34.2.4.1
Shear strength of the concrete at 0.3 % steel pt = 0.3 % is the model's planning value for a footing; the actual steel is found only after the depth is fixed	τc = 0.85 √(0.8 fck) (√(1 + 5β) − 1) ÷ (6β), β = 0.8 fck ÷ (6.89 pt)	0.85 × √(0.8 × 25) × (√(1 + 5 × β) − 1) ÷ (6 × β), β = max(1; 0.8 × 25 ÷ (6.89 × 0.3))	**0.395 N/mm²**	IS 456:2000 Table 19: the formula of the code commentary (SP 24) which the table is made from
Length of the punching perimeter at d ÷ 2 from the column	bo = 2 (b + d + D + d)	2 × (300 + 225 + 350 + 225)	**2,200 mm**	IS 456:2000 cl. 34.2.4.1(b) and cl. 31.6.3.1
Punching shear force	Vp = qu × (Lf Bf − (b + d)(D + d))	199.83 × (1.6 × 1.55 − (300 + 225) × (350 + 225) ÷ 10^6)	**435.3 kN**	IS 456:2000 cl. 34.2.4.1(b) and cl. 31.6.3.1
Column shape factor	ks = min(1 ; 0.5 + βc), βc = shorter side ÷ longer side	min(1; 0.5 + min(300; 350) ÷ max(300; 350))	**1.000**	IS 456:2000 cl. 31.6.3.1
Punching shear stress	τp = Vp ÷ (bo × d)	435.3 × 1000 ÷ (2,200 × 225)	**0.879 N/mm²**	IS 456:2000 cl. 34.2.4.1(b) and cl. 31.6.3.1
Punching shear stress allowed	ks × 0.25 √fck	1 × 0.25 × √25	**1.250 N/mm²**	IS 456:2000 cl. 31.6.3.1
Bending moment at the column face, about the Lf side	M = qu × Bf × ((Lf − D) ÷ 2)² ÷ 2	199.8 × 1.55 × ((1.6 × 1000 − 350) ÷ 2000)² ÷ 2	**60.5 kN·m**	IS 456:2000 cl. 34.2.3.1 and 34.2.3.2(a)
Bending moment at the column face, about the Bf side	M = qu × Lf × ((Bf − b) ÷ 2)² ÷ 2	199.8 × 1.6 × ((1.55 × 1000 − 300) ÷ 2000)² ÷ 2	**62.4 kN·m**	IS 456:2000 cl. 34.2.3.1 and 34.2.3.2(a)
Moment the section can carry, Lf side	Mu,lim = 0.134 fck Bf (d − 12)²	0.134 × 25 × 1.55 × 1000 × (225 − 12)² ÷ 10^6	**235.6 kN·m**	IS 456:2000 Annex G, cl. G-1.1(c): 0.36 × 0.46 × (1 − 0.42 × 0.46) = 0.134 for Fe 500
Moment the section can carry, Bf side	Mu,lim = 0.134 fck Lf (d − 12)²	0.134 × 25 × 1.6 × 1000 × (225 − 12)² ÷ 10^6	**243.2 kN·m**	IS 456:2000 Annex G, cl. G-1.1(c)
All five tests at this depth	τv ≤ τc in both directions, τp ≤ allowed, M ≤ Mu,lim in both directions		**Pass at d = 225 mm**	Engine rule

Overall depth and bars

STEP	FORMULA	WORKING	RESULT	SOURCE
Overall depth of the footing IS 456 cl. 34.1.2 asks for at least 150 mm at the edge; the model uses 150 mm and slopes the top up to the column	D = max(350 ; d + 50 + 12, up to the next 25 mm)	max(350; ceil((225 + 50 + 12) ÷ 25) × 25)	**350 mm**	IS 456:2000 cl. 26.4.2.2 (cover 50 mm for a footing); Engine rule
Effective depth of the lower layer (bars along Lf)	dX = D − 50 − 8	350 − 50 − 8	**292 mm**	IS 456:2000 cl. 26.4.2.2; Engine rule (half of a 16 mm bar)
Effective depth of the upper layer (bars along Bf)	dY = dX − 12	292 − 12	**280 mm**	Engine rule

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Minimum steel in each direction, per metre width	Ast,min = 0.0012 × 1000 × D	0.0012 × 1000 × 350	**420 mm²**	IS 456:2000 cl. 34.5.1 (as for solid slabs) and cl. 26.5.2.1 (0.12 % for high-strength deformed bars)
Steel per metre, bars along Lf Moment per metre width = M ÷ footing width; the whole width carries bars (cl. 34.3.1)	Ast = max(Ast,min ; (0.5 fck ÷ fy) (1 − √(1 − 4.6 Mu ÷ (fck b d²))) b d)	max(420; 0.5 × 25 ÷ 500 × (1 − √(1 − 4.6 × 60.5 ÷ 1.55 × 10^6 ÷ (25 × 1000 × 292²))) × 1000 × 292)	**420 mm²/m**	IS 456:2000 Annex G, cl. G-1.1(b); IS 456:2000 cl. 34.2.3.1 and 34.2.3.2(a)
Steel per metre, bars along Bf Moment per metre width = M ÷ footing width; the whole width carries bars (cl. 34.3.1)	Ast = max(Ast,min ; (0.5 fck ÷ fy) (1 − √(1 − 4.6 Mu ÷ (fck b d²))) b d)	max(420; 0.5 × 25 ÷ 500 × (1 − √(1 − 4.6 × 62.45 ÷ 1.6 × 10^6 ÷ (25 × 1000 × 280²))) × 1000 × 280)	**420 mm²/m**	IS 456:2000 Annex G, cl. G-1.1(b); IS 456:2000 cl. 34.2.3.1 and 34.2.3.2(a)
Bars along Lf	sizes tried in turn (10, 12, 16, 20 mm): spacing = largest multiple of 25 mm not over A ÷ Ast, the first of at least 100 mm, and not over min(150 ; 3d)		**10 mm at 150 mm (spacing found: 10 mm: 175 mm; cap 150 mm)**	IS 456:2000 cl. 26.3.3 allows up to 3d or 300 mm; Engine rule (150 mm cap)
Bars along Bf	same rule		**10 mm at 150 mm (spacing found: 10 mm: 175 mm; cap 150 mm)**	IS 456:2000 cl. 26.3.3; Engine rule

Bars, concrete and shuttering of this footing

STEP	FORMULA	WORKING	RESULT	SOURCE
Number of bars along Lf 50 mm kept clear at each side	n = floor((Bf − 0.1) ÷ s) + 1	floor((1.55 × 1000 − 100) ÷ 150) + 1	**10**	Engine rule
Length of each bar along Lf	L = Lf − 0.1	1.6 × 1000 − 100	**1,500 mm**	Engine rule; IS 2502:1963 cl. 5.1.1 for the cutting length (up to the next 25 mm)
Weight of the bars along Lf	W = n × L (up to 25 mm) × φ² ÷ 162.2	10 × ceil(1,500 ÷ 25) × 25 ÷ 1000 × 10² ÷ 162.2	**9.25 kg**	IS 1786:2008 (mass per metre = φ² ÷ 162.2); IS 2502:1963 cl. 5.1.1
Number of bars along Bf	n = floor((Lf − 0.1) ÷ s) + 1	floor((1.6 × 1000 − 100) ÷ 150) + 1	**11**	Engine rule
Length of each bar along Bf	L = Bf − 0.1	1.55 × 1000 − 100	**1,450 mm**	Engine rule
Weight of the bars along Bf	W = n × L (up to 25 mm) × φ² ÷ 162.2	11 × ceil(1,450 ÷ 25) × 25 ÷ 1000 × 10² ÷ 162.2	**9.83 kg**	IS 1786:2008; IS 2502:1963 cl. 5.1.1
Steel in the footing	sum of the two layers	9.248 + 9.834	**19.08 kg**	Engine rule
Plan area of the base	A1 = Lf × Bf	1.6 × 1.55	**2.480 m²**	Engine rule
Plan area of the pedestal on top	A2 = (b + 0.2)(D + 0.2)	(300 ÷ 1000 + 0.2) × (350 ÷ 1000 + 0.2)	**0.275 m²**	Engine rule: the column plus 100 mm on each side
Height of the sloping part	h = (D − 150) ÷ 1000	(350 − 150) ÷ 1000	**0.200 m**	IS 456:2000 cl. 34.1.2 (150 mm edge)
Concrete in the footing	V = A1 × 0.15 + (h ÷ 3)(A1 + A2 + √(A1 A2))	2.48 × 0.15 + (0.2 ÷ 3) × (2.48 + 0.275 + √(2.48 × 0.275))	**0.611 m³**	Engine rule: a 150 mm edge slab with a sloping top rising to the pedestal (volume of a frustum)
Shuttering of the footing	S = 2 (Lf + Bf) × 0.15	2 × (1.6 + 1.55) × 0.15	**0.945 m²**	Engine rule: the vertical edge only; the sloping top is cast against a template, not shuttered
Lean concrete under the footing (M7.5)	V = (Lf + 0.2)(Bf + 0.2) × 0.1	(1.6 + 0.2) × (1.55 + 0.2) × 0.1	**0.315 m³**	Engine rule: 100 mm thick, 100 mm wider than the footing on each side

Footing schedule

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Footings with the same column, size, depth and bars are one mark. Each mark is worked the way the footing above is; its concrete, shuttering and steel are the number of footings times the figure of one.

MARK	NO.	COLUMN (MM)	PU (KN)	LF × BF (M)	DEPTH (MM)	BARS (ALONG LF, ALONG BF)	CONCRETE (M³)	SHUTTERING (M²)	STEEL (KG)
F1	4	300 × 300	165	1.00 × 1.00	350	10@150 x, 10@150 y	1.07	2.40	31.1
F2	2	300 × 350	331	1.30 × 1.25	350	10@150 x, 10@150 y	0.83	1.53	24.6
F3	4	350 × 300	297	1.25 × 1.25	350	10@150 x, 10@150 y	1.60	3.00	45.4
F4	2	300 × 350	496	1.60 × 1.55	350	10@150 x, 10@150 y	1.22	1.89	38.2
Total	**12**						**4.72**	**8.82**	**139.2**

Footing totals and excavation

STEP	FORMULA	WORKING	RESULT	SOURCE
Concrete in the footings	Σ concrete of the marks	total of the table column = 4.72	**4.72 m³**	Engine rule
Shuttering of the footings	Σ shuttering of the marks	total of the table column = 8.82	**8.82 m²**	Engine rule
Steel in the footings	Σ steel of the marks	total of the table column = 139.2	**139.2 kg**	Engine rule
Lean concrete under the footings (M7.5)	Σ (Lf + 0.2)(Bf + 0.2) × 0.1	total over the 12 footings = 2.482	**2.48 m³**	Engine rule
Pits, one by one	Σ (Lf + 1.4)(Bf + 1.4) × depth	sum of (Lf + 1.4) × (Bf + 1.4) over the footings = 83.14, times 1.5 m	**124.7 m³**	Engine rule: 0.7 m of working space all round each footing
One pit under the whole plan	(nx × sx + 1.4)(ny × sy + 1.4) × depth	(3 × 3.663 + 1.4) × (2 × 4.227 + 1.4) × 1.5	**183.1 m³**	Engine rule: when the footings are close, the pits merge and the whole plan is dug once
Excavation	the smaller of the two	min(124.7; 183.1)	**124.7 m³**	Engine rule

Plinth beams: the rules used

STEP	FORMULA	WORKING	RESULT	SOURCE
Plinth beam width			**230 mm**	Engine rule: the width of the floor beams (Section 3)
Depth	375 mm if the span is over 4.2 m, else 300 mm		**300 or 375 mm**	NirmanShastra assumption: site practice
Bars 8 mm links in Zones III and above, 6 mm in Zone II	4 bars of 12 mm per set, links of 8 mm at 150 mm		**4-12 with 8 mm links at 150 mm**	NirmanShastra assumption: site practice
Sets of beams	one set		**1**	IS 1893 (Part 1):2002 cl. 7.12.1: in Zones IV and V individual spread footings are tied together

Plinth beam worked: along the width, span 4.23 m, 375 mm deep

STEP	FORMULA	WORKING	RESULT	SOURCE
Clear length of the beam (worked beam: the longest) Span 4.23 m between column centres, column 300 mm along the beam	Lc = L − column side ÷ 1000	4.227 − 300 ÷ 1000	**3.927 m**	Engine rule
Concrete in the beam	V = b × D × Lc	230 ÷ 1000 × 375 ÷ 1000 × 3.927	**0.3387 m³**	Engine rule
Shuttering of the beam	S = (b + 2D) × Lc	(230 ÷ 1000 + 2 × 375 ÷ 1000) × 3.927	**3.848 m²**	Engine rule: two sides and the soffit
Weight of the bars Bars run the full span between column centres	W = 4 × L × φ² ÷ 162.2	4 × ceil(4,227 ÷ 25) × 25 ÷ 1000 × 12² ÷ 162.2	**15.09 kg**	IS 1786:2008; IS 2502:1963 cl. 5.1.1

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Cut length of one link	Ls = 2 (A + E) + 12φ (+ tails of a small bar)	2 × ((230 – 50) + (375 – 50)) + 12 × 8 + 2 × max(0; 75 – 10 × 8)	**1,106 mm**	Engine rule: the cut length of a closed link with 135° hooks, 25 mm cover, derived from the bar's geometry (see Section 11)
Number of links	n = ceil(Lc ÷ 150) + 1	ceil(3.927 × 1000 ÷ 150) + 1	**28**	Engine rule
Weight of the links	W = n × Ls × φ² ÷ 162.2	28 × ceil(1,106 ÷ 25) × 25 ÷ 1000 × 8² ÷ 162.2	**12.43 kg**	IS 1786:2008; IS 2502:1963 cl. 5.1.1
Steel in the beam	bars + links	15.09 + 12.43	**27.52 kg**	Engine rule

Plinth beams: schedule

Beams along the length and the width are listed together when span, depth and column size agree.

NO.	SPAN (M)	CLEAR (M)	DEPTH (MM)	CONCRETE EACH (M³)	SHUTTERING EACH (M²)	STEEL EACH (KG)	CONCRETE (M³)	SHUTTERING (M²)	STEEL (KG)
5	3.66	3.363	300	0.232	2.791	22.3	1.16	13.96	111.4
4	3.66	3.313	300	0.229	2.750	22.3	0.91	11.00	89.1
4	4.23	3.927	375	0.339	3.848	27.5	1.35	15.39	110.1
4	4.23	3.877	375	0.334	3.799	27.1	1.34	15.20	108.3
17							**4.77**	**55.55**	**418.9**

Plinth beam totals

STEP	FORMULA	WORKING	RESULT	SOURCE
Concrete in the plinth beams	Σ over the beams	total of the table column = 4.767	**4.77 m³**	Engine rule
Shuttering of the plinth beams	Σ over the beams	total of the table column = 55.55	**55.55 m²**	Engine rule
Steel in the plinth beams	Σ over the beams	total of the table column = 418.9	**418.9 kg**	Engine rule
Number of plinth beams	lines × sets	17 × 1	**17**	Engine rule

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9. Floor slabs and staircase

Each floor slab is a set of two-way panels designed from the coefficients of IS 456 Table 26. The staircase is a dog-legged flight with landings; its opening is taken out of the floor slabs. Both the steel and the concrete are counted here and carried to the take-off.

Slab panels: method

STEP	FORMULA	WORKING	RESULT	SOURCE
Slab thickness Fixed by the span to depth rule; the same for every slab			**150 mm**	Section 3
Number of slab panels 2 storeys; each bay of each floor is one panel			**12**	Section 3
Method The slab is designed as two-way in every panel; the load comes from Section 4 and the beams carry the equivalent loads found there	IS 456 Annex D (rectangular panels supported on four sides with torsion at the corners)		**Mx = αx wu lx², My = αy wu lx², coefficients from Table 26**	IS 456:2000 cl. 24.4 and Annex D
Bars Minimum steel 0.12 % of the section (IS 456:2000 cl. 26.5.2.1)	sizes 8, 10, 12, 16 mm tried in turn		**spacing in steps of 25 mm, not under 75 mm and not over 150 mm**	Engine rule

Only the panels of the building are designed here. Deflection is controlled by the thickness rule of Section 3; shear in slabs, crack width and edge beam torsion are not checked.

Worked panel: the largest moment, Table 26 case 4

8 of the 12 panels are of this case. The same steps are run for every panel; the schedule below lists the result.

STEP	FORMULA	WORKING	RESULT	SOURCE
Panel The slab at the top of that storey			**Level 1, bay 1,1**	Section 3
Span along the length (centre to centre)			**3.66 m**	Section 3
Span along the width (centre to centre)			**4.23 m**	Section 3
Shorter span	lx = smaller of the two	min(3.663; 4.227)	**3.66 m**	IS 456:2000 Table 26
Longer span	ly = larger of the two	max(3.663; 4.227)	**4.23 m**	IS 456:2000 Table 26
Ratio of the spans	ly ÷ lx	4.227 ÷ 3.663	**1.154**	IS 456:2000 Table 26
Edges of the panel A balcony beyond an edge is not counted as continuous	an edge is continuous when another panel of the same floor lies beyond it		**1 short edge and 1 long edge discontinuous**	Engine rule
Table 26 case	by the edges that are discontinuous		**Case 4: two adjacent edges discontinuous**	IS 456:2000 Table 26
Dead load on the panel Floor slab			**5.500 kN/m²**	Section 4
Imposed load on the panel			**2.00 kN/m²**	Section 4
Factored load	wu = 1.5 (g + q)	1.5 × (5.5 + 2)	**11.250 kN/m²**	IS 456:2000 Table 18

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Effective depth, bars along the short span A 10 mm bar is assumed for the half-bar allowance whatever bar is chosen	dx = t − cover − half a bar	150 − 20 − 5	**125 mm**	Section 2 (cover); Engine rule
Effective depth, bars along the long span The long-span bars lie on top of the short-span bars	dy = dx − one bar	125 − 10	**115 mm**	Engine rule
Minimum steel	Ast,min = 0.0012 b t	0.0012 × 1000 × 150	**180 mm²/m**	IS 456:2000 cl. 26.5.2.1 (0.12 % for high-strength deformed bars)
αx at mid-span Between the tabulated values for ly/lx = 1.10 and 1.20	α = a1 + (a2 − a1)(r − r1) ÷ (r2 − r1)	0.04 + (0.045 − 0.04) × (1.154 − 1.1) ÷ (1.2 − 1.1)	**0.0427**	IS 456:2000 Table 26
αx at a continuous edge Between the tabulated values for ly/lx = 1.10 and 1.20	α = a1 + (a2 − a1)(r − r1) ÷ (r2 − r1)	0.053 + (0.06 − 0.053) × (1.154 − 1.1) ÷ (1.2 − 1.1)	**0.0568**	IS 456:2000 Table 26
αy at mid-span The same for all ratios			**0.035**	IS 456:2000 Table 26
αy at a continuous edge The same for all ratios			**0.047**	IS 456:2000 Table 26
Mid-span moment, short span	Mx = α wu lx²	0.0427 × 11.25 × 3.6632²	**6.45 kN·m/m**	IS 456:2000 Table 26; IS 456:2000 cl. D-1.1
Mid-span moment, long span	My = α wu lx²	0.035 × 11.25 × 3.663²	**5.28 kN·m/m**	IS 456:2000 Table 26; IS 456:2000 cl. D-1.1
Moment at a continuous long edge	Mx = α wu lx²	0.0568 × 11.25 × 3.6632²	**8.57 kN·m/m**	IS 456:2000 Table 26; IS 456:2000 cl. D-1.1
Moment at a continuous short edge	My = α wu lx²	0.047 × 11.25 × 3.6632²	**7.10 kN·m/m**	IS 456:2000 Table 26; IS 456:2000 cl. D-1.1
Steel at mid-span, short span	Ast = max(Ast,min ; 0.5 fck/fy (1 − √(1 − 4.6 Mu/(fck b d²))) b d)	max(180; 0.5 × 20 ÷ 500 × (1 − √(1 − 4.6 × 6.445 × 10^6 ÷ (20 × 1000 × 125²))) × 1000 × 125)	**180 mm²/m**	IS 456:2000 Annex G, cl. G-1.1(b)
Steel at mid-span, long span	Ast = max(Ast,min ; Annex G steel for Mu)	max(180; 0.5 × 20 ÷ 500 × (1 − √(1 − 4.6 × 5.284 × 10^6 ÷ (20 × 1000 × 115²))) × 1000 × 115)	**180 mm²/m**	IS 456:2000 Annex G, cl. G-1.1(b)
Steel at a continuous long edge	Ast = max(Ast,min ; Annex G steel for Mu)	max(180; 0.5 × 20 ÷ 500 × (1 − √(1 − 4.6 × 8.57 × 10^6 ÷ (20 × 1000 × 125²))) × 1000 × 125)	**180 mm²/m**	IS 456:2000 Annex G, cl. G-1.1(b)
Steel at a continuous short edge	Ast = max(Ast,min ; Annex G steel for Mu)	max(180; 0.5 × 20 ÷ 500 × (1 − √(1 − 4.6 × 7.095 × 10^6 ÷ (20 × 1000 × 115²))) × 1000 × 115)	**180 mm²/m**	IS 456:2000 Annex G, cl. G-1.1(b)
Steel for the corners (torsion) The code takes three-quarters of the area REQUIRED for the mid-span moment; the model takes three-quarters of the area PROVIDED, which is a little more	Ast,t = 0.75 × steel provided at mid-span, short span	0.75 × 335.1	**251 mm²/m**	IS 456:2000 cl. D-1.8

Bar sizes and spacing

STEEL	NEEDED (MM²/M)	D (MM)	WIDEST SPACING (MM)	SIZES TRIED: SPACING FOUND (MM)	CHOSEN	PROVIDED (MM²/M)
Bottom, along the short span	180	125	150	8: 275 (taken)	8 mm at 150 mm	335
Bottom, along the long span	180	115	150	8: 275 (taken)	8 mm at 150 mm	335
Top, over a continuous long edge	180	125	150	8: 275 (taken)	8 mm at 150 mm	335

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Top, over a continuous short edge	180	115	150	8: 275 (taken)	8 mm at 150 mm	335
Corners (torsion)	251	125	150	8: 200 (taken)	8 mm at 150 mm	335

Bars of the panel

BARS	SIZE (MM)	CUT LENGTH (MM)	NUMBER	WEIGHT (KG)	RULE
Bottom bars along the short span	8	3,625	28	40.0	lx – 50 ; (ly – 100) ÷ s + 1
Bottom bars along the long span	8	4,200	24	39.8	ly – 50 ; (lx – 100) ÷ s + 1
Top bars over the continuous long edges	8	1,225	28	13.5	(2 × 0.3 lx + beam width) ÷ 2 ; edges × ((ly – 100) ÷ s + 1)
Top bars over the continuous short edges	8	1,400	24	13.3	(2 × 0.3 ly + beam width) ÷ 2 ; edges × ((lx – 100) ÷ s + 1)
Top bars at a discontinuous long edge	8	875	14	4.8	0.15 span + beam width – 20 + (t – 40) ; (edge – 100) ÷ min(300; 2 s) + 1
Top bars at a discontinuous short edge	8	975	12	4.6	0.15 span + beam width – 20 + (t – 40) ; (edge – 100) ÷ min(300; 2 s) + 1
Torsion bars at a corner with two discontinuous edges	8	750	20	5.9	lx ÷ 5 ; 2 layers × 2 directions × (lx ÷ 5 ÷ s + 1), half at a corner with one discontinuous edge
Torsion bars at a corner with one discontinuous edge	8	750	10	3.0	lx ÷ 5 ; 2 layers × 2 directions × (lx ÷ 5 ÷ s + 1), half at a corner with one discontinuous edge
Torsion bars at a corner with one discontinuous edge	8	750	10	3.0	lx ÷ 5 ; 2 layers × 2 directions × (lx ÷ 5 ÷ s + 1), half at a corner with one discontinuous edge
Steel in the panel				**127.9**	

Against IS 456 Annex D: mid-span bars run the full span less 50 mm and none are curtailed (cl. D-1.4 lets some stop short). Over a continuous edge the code (D-1.5) takes the bars 0.15 l from the support with at least half of them to 0.3 l; the model takes all of them to 0.3 l. At a discontinuous edge D-1.6 asks for half the mid-span steel reaching 0.1 l; the model uses the mid-span bar at twice the spacing for 0.15 l. Corner steel follows D-1.8 to D-1.10 (none where both edges are continuous, half where one is).

Steel in the panel

STEP	FORMULA	WORKING	RESULT	SOURCE
Steel in the panel	sum of the bar weights	40.05 + 39.77 + 13.53 + 13.26 + 4.834 + 4.617 + 5.919 + 2.959 + 2.959	**127.9 kg**	Engine rule

Worked panel: Table 26 case 2

4 panels are of this case; the panel with the largest moment is worked.

STEP	FORMULA	WORKING	RESULT	SOURCE
Panel The slab at the top of that storey			**Level 1, bay 2,1**	Section 3
Span along the length (centre to centre)			**3.66 m**	Section 3
Span along the width (centre to centre)			**4.23 m**	Section 3
Shorter span	lx = smaller of the two	min(3.663; 4.227)	**3.66 m**	IS 456:2000 Table 26
Longer span	ly = larger of the two	max(3.663; 4.227)	**4.23 m**	IS 456:2000 Table 26
Ratio of the spans	ly ÷ lx	4.227 ÷ 3.663	**1.154**	IS 456:2000 Table 26
Edges of the panel A balcony beyond an edge is not counted as continuous	an edge is continuous when another panel of the same floor lies beyond it		**1 short edge and 0 long edges discontinuous**	Engine rule

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Table 26 case	by the edges that are discontinuous		**Case 2: one short edge discontinuous**	IS 456:2000 Table 26
Dead load on the panel Floor slab			**5.500 kN/m²**	Section 4
Imposed load on the panel			**2.00 kN/m²**	Section 4
Factored load	wu = 1.5 (g + q)	1.5 × (5.5 + 2)	**11.250 kN/m²**	IS 456:2000 Table 18
Effective depth, bars along the short span A 10 mm bar is assumed for the half-bar allowance whatever bar is chosen	dx = t − cover − half a bar	150 − 20 − 5	**125 mm**	Section 2 (cover); Engine rule
Effective depth, bars along the long span The long-span bars lie on top of the short-span bars	dy = dx − one bar	125 − 10	**115 mm**	Engine rule
Minimum steel	Ast,min = 0.0012 b t	0.0012 × 1000 × 150	**180 mm²/m**	IS 456:2000 cl. 26.5.2.1 (0.12 % for high-strength deformed bars)
αx at mid-span Between the tabulated values for ly/lx = 1.10 and 1.20	α = a1 + (a2 − a1)(r − r1) ÷ (r2 − r1)	0.032 + (0.036 − 0.032) × (1.154 − 1.1) ÷ (1.2 − 1.1)	**0.0342**	IS 456:2000 Table 26
αx at a continuous edge Between the tabulated values for ly/lx = 1.10 and 1.20	α = a1 + (a2 − a1)(r − r1) ÷ (r2 − r1)	0.043 + (0.048 − 0.043) × (1.154 − 1.1) ÷ (1.2 − 1.1)	**0.0457**	IS 456:2000 Table 26
αy at mid-span The same for all ratios			**0.028**	IS 456:2000 Table 26
αy at a continuous edge The same for all ratios			**0.037**	IS 456:2000 Table 26
Mid-span moment, short span	Mx = α wu lx²	0.0342 × 11.25 × 3.6632²	**5.16 kN·m/m**	IS 456:2000 Table 26; IS 456:2000 cl. D-1.1
Mid-span moment, long span	My = α wu lx²	0.028 × 11.25 × 3.663²	**4.23 kN·m/m**	IS 456:2000 Table 26; IS 456:2000 cl. D-1.1
Moment at a continuous long edge	Mx = α wu lx²	0.0457 × 11.25 × 3.6632²	**6.90 kN·m/m**	IS 456:2000 Table 26; IS 456:2000 cl. D-1.1
Moment at a continuous short edge	My = α wu lx²	0.037 × 11.25 × 3.663²	**5.59 kN·m/m**	IS 456:2000 Table 26; IS 456:2000 cl. D-1.1
Steel at mid-span, short span	Ast = max(Ast,min ; 0.5 fck/fy (1 − √(1 − 4.6 Mu/(fck b d²))) b d)	max(180; 0.5 × 20 ÷ 500 × (1 − √(1 − 4.6 × 5.156 × 10^6 ÷ (20 × 1000 × 125²))) × 1000 × 125)	**180 mm²/m**	IS 456:2000 Annex G, cl. G-1.1(b)
Steel at mid-span, long span	Ast = max(Ast,min ; Annex G steel for Mu)	max(180; 0.5 × 20 ÷ 500 × (1 − √(1 − 4.6 × 4.227 × 10^6 ÷ (20 × 1000 × 115²))) × 1000 × 115)	**180 mm²/m**	IS 456:2000 Annex G, cl. G-1.1(b)
Steel at a continuous long edge	Ast = max(Ast,min ; Annex G steel for Mu)	max(180; 0.5 × 20 ÷ 500 × (1 − √(1 − 4.6 × 6.898 × 10^6 ÷ (20 × 1000 × 125²))) × 1000 × 125)	**180 mm²/m**	IS 456:2000 Annex G, cl. G-1.1(b)
Steel at a continuous short edge	Ast = max(Ast,min ; Annex G steel for Mu)	max(180; 0.5 × 20 ÷ 500 × (1 − √(1 − 4.6 × 5.586 × 10^6 ÷ (20 × 1000 × 115²))) × 1000 × 115)	**180 mm²/m**	IS 456:2000 Annex G, cl. G-1.1(b)
Steel for the corners (torsion) The code takes three-quarters of the area REQUIRED for the mid-span moment; the model takes three-quarters of the area PROVIDED, which is a little more	Ast,t = 0.75 × steel provided at mid-span, short span	0.75 × 335.1	**251 mm²/m**	IS 456:2000 cl. D-1.8

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Bar sizes and spacing

STEEL	NEEDED (MM²/M)	D (MM)	WIDEST SPACING (MM)	SIZES TRIED: SPACING FOUND (MM)	CHOSEN	PROVIDED (MM²/M)
Bottom, along the short span	180	125	150	8: 275 (taken)	8 mm at 150 mm	335
Bottom, along the long span	180	115	150	8: 275 (taken)	8 mm at 150 mm	335
Top, over a continuous long edge	180	125	150	8: 275 (taken)	8 mm at 150 mm	335
Top, over a continuous short edge	180	115	150	8: 275 (taken)	8 mm at 150 mm	335
Corners (torsion)	251	125	150	8: 200 (taken)	8 mm at 150 mm	335

Bars of the panel

BARS	SIZE (MM)	CUT LENGTH (MM)	NUMBER	WEIGHT (KG)	RULE
Bottom bars along the short span	8	3,625	28	40.0	lx – 50 ; (ly – 100) ÷ s + 1
Bottom bars along the long span	8	4,200	24	39.8	ly – 50 ; (lx – 100) ÷ s + 1
Top bars over the continuous long edges	8	1,225	56	27.1	(2 × 0.3 lx + beam width) ÷ 2 ; edges × ((ly – 100) ÷ s + 1)
Top bars over the continuous short edges	8	1,400	24	13.3	(2 × 0.3 ly + beam width) ÷ 2 ; edges × ((lx – 100) ÷ s + 1)
Top bars at a discontinuous short edge	8	975	12	4.6	0.15 span + beam width – 20 + (t – 40) ; (edge – 100) ÷ min(300; 2 s) + 1
Torsion bars at a corner with one discontinuous edge	8	750	10	3.0	lx ÷ 5 ; 2 layers × 2 directions × (lx ÷ 5 ÷ s + 1), half at a corner with one discontinuous edge
Torsion bars at a corner with one discontinuous edge	8	750	10	3.0	lx ÷ 5 ; 2 layers × 2 directions × (lx ÷ 5 ÷ s + 1), half at a corner with one discontinuous edge
Steel in the panel				**130.7**	

Steel in the panel

STEP	FORMULA	WORKING	RESULT	SOURCE
Steel in the panel	sum of the bar weights	40.05 + 39.77 + 27.07 + 13.26 + 4.617 + 2.959 + 2.959	**130.7 kg**	Engine rule

Schedule of slab panels

MARK	SLAB AT	PANELS	CASE	LX × LY (M)	WU (KN/M²)	CONTINUOUS EDGES	BOTTOM BARS (SHORT / LONG)	STEEL EACH (KG)	STEEL TOTAL (KG)
S1	Level 1, Roof	2	4	3.66 × 4.23	11.25	E N	8@150 / 8@150	127.9	255.8
S2	Level 1, Roof	2	4	3.66 × 4.23	11.25	E S	8@150 / 8@150	127.9	255.8
S3	Level 1, Roof	2	2	3.66 × 4.23	11.25	W E N	8@150 / 8@150	130.7	261.4
S4	Level 1, Roof	2	2	3.66 × 4.23	11.25	W E S	8@150 / 8@150	130.7	261.4
S5	Level 1, Roof	2	4	3.66 × 4.23	11.25	W N	8@150 / 8@150	127.9	255.8
S6	Level 1, Roof	2	4	3.66 × 4.23	11.25	W S	8@150 / 8@150	127.9	255.8
Total		**12**							**1,545.9**

W and E are the two ends of the plan along its length, S and N the two sides. Panels with the same case, spans, load and continuous edges have the same steel.

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Total of the panel steel

STEP	FORMULA	WORKING	RESULT	SOURCE
Steel in all panels, before the corrections of the next table	sum of the schedule	1,545.9	**1,545.9 kg**	Engine rule

Staircase: geometry

STEP	FORMULA	WORKING	RESULT	SOURCE
Storey height			**3.0 m**	Section 3
Riser			**0.15 m**	NirmanShastra assumption: a usual residential riser (150 mm)
Tread			**0.25 m**	NirmanShastra assumption: a usual residential tread (250 mm)
Width of a flight			**1.0 m**	NirmanShastra assumption
Risers needed in one flight, before rounding A dog-legged stair: two equal flights and a landing in each storey	n = H ÷ R ÷ 2	3 ÷ 0.15 ÷ 2	**10.00**	Engine rule
Risers in one flight	n = round(n)	round(10)	**10**	Engine rule
Treads in one flight	n − 1	10 − 1	**9**	Engine rule
Horizontal length of one flight	run = treads × T	9 × 0.25	**2.25 m**	Engine rule
Height climbed in one flight	rise = n × R	10 × 0.15	**1.50 m**	Engine rule
Length of the flight along the slope	√(run² + rise²)	√(2.25² + 1.5²)	**2.704 m**	Engine rule
Effective span of the flight The model takes the run plus 0.25 m, half of a landing support, as a planning figure	span = run + 0.25	2.25 + 0.25	**2.50 m**	IS 456:2000 cl. 33.1 sets the effective span by how the flight is supported; Engine rule

Staircase: thickness and load

STEP	FORMULA	WORKING	RESULT	SOURCE
Waist thickness needed, before rounding	d = span ÷ (20 × 1.2)	2.5 × 1000 ÷ (20 × 1.2)	**104.2 mm**	IS 456:2000 cl. 23.2.1 (basic ratio 20 for a simply supported span); NirmanShastra assumption (modification factor 1.2)
Waist thickness Cover 20 mm and half of a 12 mm bar	t = d + 20 + 6, up to the next 25 mm, not under 125 mm	max(125; ceil((104.2 + 20 + 6) ÷ 25) × 25)	**150 mm**	IS 456:2000 cl. 33.3 for the depth of the section; Engine rule
Slope factor The waist weighs more per metre of plan than per metre along the slope	sloped length ÷ run	2.704 ÷ 2.25	**1.202**	Engine rule
Weight of the waist slab per m² of plan	γ × t × slope factor	25 × 150 ÷ 1000 × 1.2019	**4.507 kN/m²**	IS 456:2000 cl. 19.2.1 (25 kN/m³)
Weight of the steps per m² of plan	γ × R ÷ 2	25 × 0.5 × 0.15	**1.875 kN/m²**	Engine rule: the triangular steps have an average height of half the riser
Dead load	g = waist + steps + finish	4.507 + 1.875 + 1	**7.382 kN/m²**	NirmanShastra assumption: finish 1.0 kN/m²

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Imposed load on the stair Dwelling houses: staircases 3.0 kN/m²			**3.0 kN/m²**	IS 875 (Part 2):1987 Table 1
Factored load	wu = 1.5 (g + q)	1.5 × (7.382 + 3)	**15.573 kN/m²**	IS 456:2000 Table 18

Staircase: bending and bars

STEP	FORMULA	WORKING	RESULT	SOURCE
Bending moment per metre width	M = wu × span² ÷ 8	15.573 × 2.5² ÷ 8	**12.17 kN·m**	Engine rule: the waist is designed as simply supported
Effective depth	d = t − 20 − 6	150 − 20 − 6	**124 mm**	Engine rule
Minimum steel per metre	Ast,min = 0.0012 × 1000 × t	0.0012 × 1000 × 150	**180 mm²**	IS 456:2000 cl. 26.5.2.1 (0.12 % of the section for high-strength deformed bars)
Steel per metre	Ast = max(Ast,min ; (0.5 fck ÷ fy) (1 − √(1 − 4.6 Mu ÷ (fck b d²))) b d)	max(180; 0.5 × 20 ÷ 500 × (1 − √(1 − 4.6 × 12.17 × 10^6 ÷ (20 × 1000 × 124²))) × 1000 × 124)	**237 mm²/m**	IS 456:2000 Annex G, cl. G-1.1(b)
Main bars	sizes 10, 12, 16 mm tried in turn: the first whose spacing (largest multiple of 25 mm not over A ÷ Ast) is at least 100 mm; spacing capped at 150 mm		**10 mm at 150 mm (spacings that fit: 10 mm at 325 mm)**	IS 456:2000 cl. 26.3.3 allows up to 3d or 300 mm; Engine rule (150 mm cap)
Distribution bars	8 mm at 200 mm		**8 mm at 200 mm (0.12 % of the waist is 180 mm²/m; provided 251 mm²/m)**	IS 456:2000 cl. 26.5.2.1 and 26.3.3(b)(2) (not over 5d or 450 mm)
Landing	10 mm at 150 mm each way, 150 mm thick		**10 mm at 150 mm each way**	NirmanShastra assumption: site practice

Staircase: bars

BARS	SIZE (MM)	CUT LENGTH (MM)	NUMBER	RULE	WEIGHT (KG)
Main bars along the flights	10	3,304	28	sloped length + 600; number = flights × ((width − 100) ÷ s + 1)	57.4
Distribution bars across the flights	8	950	56	width − 50; number = flights × (sloped length ÷ 200 + 1)	21.0
Landing bars along the landing length	10	1,000	28	landing length − 50; number = storeys × ((landing width − 100) ÷ 150 + 1)	17.3
Landing bars along the landing width	10	2,050	14	landing width − 50; number = storeys × ((landing length − 100) ÷ 150 + 1)	17.7
Steel in the staircase					**113.3**

Each length is taken up to the next 25 mm and weighed at φ² ÷ 162.2 kg per metre (IS 2502:1963 cl. 5.1.1; IS 1786:2008). Landing: 1,050 × 2,100 mm.

Staircase: concrete and shuttering

STEP	FORMULA	WORKING	RESULT	SOURCE
Flights in the building	2 per storey	2 × 2	**4**	Engine rule: every storey has a stair up to the next level, the top one to the roof
Concrete in the waist of one flight	V = sloped length × width × t	2.704 × 1 × 150 ÷ 1000	**0.406 m³**	Engine rule

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Concrete in the steps of one flight	V = n × (R ÷ 2) × T × width	10 × 0.5 × 0.15 × 0.25 × 1	**0.188 m³**	Engine rule: each step is a triangle of riser R and tread T
Concrete in one landing	V = landing × (2 × width + gap) × 0.15	1.05 × (2 × 1 + 0.1) × 0.15	**0.331 m³**	Engine rule
Concrete in the staircase	V = storeys × (2 × flight + landing)	2 × (2 × (0.4056 + 0.1875) + 0.3308)	**3.03 m³**	Engine rule
Shuttering: soffit of the two flights	2 × sloped length × width	2 × 2.704 × 1	**5.408 m²**	Engine rule
Shuttering: risers of the two flights	2 × n × R × width	2 × 10 × 0.15 × 1	**3.000 m²**	Engine rule
Shuttering: sides of the two flights	4 × sloped length × (t + 0.12)	4 × 2.704 × (150 ÷ 1000 + 0.12)	**2.920 m²**	Engine rule: the waist plus 0.12 m for the step profile
Shuttering: soffit of the landing	landing × (2 × width + gap)	1.05 × (2 × 1 + 0.1)	**2.205 m²**	Engine rule
Shuttering: edges of the landing	2 (landing + 2 × width + gap) × 0.15	2 × (1.05 + 2 × 1 + 0.1) × 0.15	**0.945 m²**	Engine rule
Shuttering of the staircase	S = storeys × (sum of the parts)	2 × (5.408 + 3 + 2.92 + 2.205 + 0.945)	**28.96 m²**	Engine rule
Steel in the staircase	sum of the bar table	113.3	**113.3 kg**	Engine rule

Staircase: the opening in the slabs

STEP	FORMULA	WORKING	RESULT	SOURCE
Length of the stair opening in each floor slab	run + landing	2.25 + 1.05	**3.30 m**	Engine rule
Width of the stair opening	2 × width + gap	2 × 1 + 0.1	**2.10 m**	Engine rule
Area of the stair opening Taken out of every floor slab below the roof; the slab concrete, shuttering and steel are reduced for it in the next part	length × width	3.3 × 2.1	**6.93 m²**	Engine rule

Quantities of the slab at Level 1

STEP	FORMULA	WORKING	RESULT	SOURCE
Slab			**Level 1**	Section 3
Floor plate of the modelled bays (Level 1)	bays × sx × bays × sy	3 × 3.663 × 2 × 4.227	**92.90 m²**	Section 3
Stair opening taken out of the slab	smaller of the opening and 12 % of the plate	min(6.93; 0.12 × 92.9)	**6.93 m²**	Engine rule; opening from the staircase part of this Section
Correction to the entered floor area Models the bays as a whole number; the entered area is matched by this factor			**1.0000**	Section 3
Trim of the steel round the opening The steel is cut by 85 % of the opening's share of the plate	f = 1 − 0.85 × opening ÷ plate	1 − 0.85 × 6.93 ÷ 92.9	**0.9366**	Engine rule
Steel in the panels of this slab (before corrections)			**773.0 kg**	Schedule above
Steel in the slab	panels × trim × floor-area correction	772.97 × 0.9366 × 1	**724.0 kg**	Engine rule
Concrete in the slab	V = (plate − opening) × t × correction	(92.9 − 6.93) × 150 ÷ 1000 × 1	**12.896 m³**	Engine rule

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Plate area for shuttering The edge of the opening is 2 (length + width) × slab thickness	plate − opening + edge of the opening	92.903 − 6.93 + 1.62	**87.593 m²**	Engine rule
Footprint of the beams on the slab 17 beams; 0.3 m is taken off each span for the columns	width × (sum of spans − 0.3 per beam)	230 ÷ 1000 × (66.784 − 0.3 × 17)	**14.187 m²**	Engine rule
Footprint of the columns on the slab	sum of b × D	1.2	**1.200 m²**	Section 7 (12 columns)
Shuttering of the slab (soffit) The sides of the beams are counted with the beams (Section 12)	plate × correction − beams × correction − columns	max(0; 87.593 × 1 − 14.187 × 1 − 1.2)	**72.21 m²**	Engine rule

Quantities of all floor slabs

SLAB AT	PANELS	PLATE (M²)	OPENING (M²)	STEEL TRIM	AREA CORRECTION	STEEL (KG)	CONCRETE (M³)	SHUTTERING (M²)
Level 1	6	92.90	6.93	0.9366	1.0000	724.0	12.896	72.21
Roof	6	92.90	0.00	1.0000	1.0000	773.0	13.935	77.52
All slabs	**12**					**1,496.9**	**26.831**	**149.72**

Totals for the floor slabs

STEP	FORMULA	WORKING	RESULT	SOURCE
Steel in all floor slabs	sum of the table	1,496.9	**1,496.9 kg**	Engine rule
Concrete in all floor slabs	sum of the table	26.83	**26.83 m³**	Engine rule
Shuttering of all floor slabs	sum of the table	149.7	**149.7 m²**	Engine rule

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10. Balconies and small RCC items

No balconies were asked for. The small items (lintels, sunshades, the parapet band and the stair head-room roof) are counted from the plan with the usual site sizes.

Small RCC items: sizes the model uses

None of these sizes comes from a code; they are the usual sizes of site practice (NirmanShastra assumption). The counts come from the plan.

ITEM	SIZE AND BARS	BASIS
Window	1.2 m wide, one every 3.6 m of outer wall (at least 2 on a storey)	Opening model
Main door	1.2 m wide, one, on the storey of the entrance	Opening model
Internal door	1 m wide in a 115 mm partition, one per 13 m² of floor	Opening model
Lintel	150 mm deep, 200 mm bearing each side; 10 mm bars at the bottom (3, or 2 in a wall under 200 mm) and 2 of 8 mm at the top; 6 mm stirrups at 150 mm	Site practice
Sunshade	450 mm projection, 75 mm thick, 300 mm wider than the opening; 8 mm at 150 mm main bars with 350 mm anchorage; 6 mm at 200 mm distribution	Site practice
Terrace parapet band	115 × 75 mm along the roof edge, 2 bars of 8 mm (5 % more for laps and corners), 6 mm stirrups at 250 mm	Site practice
Stair head-room roof	100 mm slab with 8 mm at 150 mm each way, 300 mm overhang; 230 × 230 mm ring beam with 4 bars of 10 mm and 6 mm stirrups at 150 mm	Site practice

Openings counted at Level 1

STEP	FORMULA	WORKING	RESULT	SOURCE
Perimeter (Level 1)	p = 2 (bays × sx + bays × sy) × √correction	2 × (3 × 3.663 + 2 × 4.227) × √1	**38.89 m**	Section 3
Windows	larger of 2 and p ÷ 3.6, rounded	max(2; round(38.89 ÷ 3.6))	**11**	Engine rule
Internal doors	larger of 1 and area ÷ 13, rounded	max(1; round(92.9 ÷ 13))	**7**	Engine rule

Openings on every storey

STOREY	PERIMETER (M)	WINDOWS	MAIN DOOR	INTERNAL DOORS
Level 1	38.89	11	1	7
Roof	38.89	11	0	7
Total		**22**	**1**	**14**

Lintel: the window lintel worked

STEP	FORMULA	WORKING	RESULT	SOURCE
Length of a window lintel	L = opening + 2 × bearing	1.2 + 2 × 0.2	**1.60 m**	Engine rule
Bottom bars (3 of 10 mm) Each is the lintel length less 50 mm	n × φ² ÷ 162.2 × L	3 × (10² ÷ 162.2) × 1,550 ÷ 1000	**2.9 kg**	Engine rule
Top bars (2 of 8 mm)	n × φ² ÷ 162.2 × L	2 × (8² ÷ 162.2) × 1,550 ÷ 1000	**1.2 kg**	Engine rule
Number of stirrups	(L − 100) ÷ 150 + 1	floor((1.6 × 1000 − 100) ÷ 150) + 1	**11**	Engine rule
Cut length of a stirrup	Ls = 2 (A + E) + 12 φ + 2 × tail extra	2 × (180 + 100) + 12 × 6 + 2 × max(0; 75 − 10 × 6)	**662 mm**	Engine rule; cover 50 mm each side

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Stirrups (6 mm)	n × φ² ÷ 162.2 × L	11 × (6² ÷ 162.2) × 675 ÷ 1000	**1.6 kg**	Engine rule
Steel in one lintel	sum of the bars	2.867 + 1.223 + 1.648	**5.74 kg**	Engine rule
Concrete in one lintel	V = L × wall thickness × depth	1.6 × 0.23 × 0.15	**0.0552 m³**	Engine rule
Shuttering of one lintel	S = L × (wall thickness + 2 × depth)	1.6 × (0.23 + 2 × 0.15)	**0.848 m²**	Engine rule

Lintels

TYPE	NUMBER	LENGTH (M)	STEEL EACH (KG)	CONCRETE EACH (M³)	SHUTTERING EACH (M²)	STEEL (KG)	CONCRETE (M³)	SHUTTERING (M²)
Window	22	1.60	5.74	0.0552	0.848	126.2	1.214	18.66
Main door	1	1.60	5.74	0.0552	0.848	5.7	0.055	0.85
Internal door	14	1.40	3.63	0.0242	0.581	50.8	0.338	8.13
All lintels	**37**					**182.8**	**1.608**	**27.64**

Sunshade: the window sunshade worked

STEP	FORMULA	WORKING	RESULT	SOURCE
Length of a window sunshade	L = opening + 0.3	1.2 + 0.3	**1.50 m**	Engine rule
Number of main bars	(L − 100) ÷ s + 1	floor((1.5 × 1000 − 100) ÷ 150) + 1	**10**	Engine rule
Main bars (8 mm) Each is the projection plus 350 mm anchorage into the wall	n × φ² ÷ 162.2 × L	10 × (8² ÷ 162.2) × 800 ÷ 1000	**3.2 kg**	Engine rule
Number of distribution bars	projection ÷ s + 1	floor(0.45 × 1000 ÷ 200) + 1	**3**	Engine rule
Distribution bars (6 mm) Each is the sunshade length less 50 mm	n × φ² ÷ 162.2 × L	3 × (6² ÷ 162.2) × 1,450 ÷ 1000	**1.0 kg**	Engine rule
Steel in one sunshade	sum of the bars	3.157 + 0.965	**4.12 kg**	Engine rule
Concrete in one sunshade	V = L × projection × thickness	1.5 × 0.45 × 0.075	**0.0506 m³**	Engine rule
Shuttering of one sunshade	S = L × projection + (L + 2 × projection) × thickness	1.5 × 0.45 + (1.5 + 2 × 0.45) × 0.075	**0.855 m²**	Engine rule

Sunshades

TYPE	NUMBER	LENGTH (M)	STEEL EACH (KG)	CONCRETE EACH (M³)	SHUTTERING EACH (M²)	STEEL (KG)	CONCRETE (M³)	SHUTTERING (M²)
Window	22	1.50	4.12	0.0506	0.855	90.7	1.114	18.81
Main door	1	1.50	4.12	0.0506	0.855	4.1	0.051	0.86
All sunshades	**23**					**94.8**	**1.164**	**19.67**

Terrace parapet band

STEP	FORMULA	WORKING	RESULT	SOURCE
Length of the terrace parapet band	p = 2 (bays × sx + bays × sy) × √correction, top storey	2 × (3 × 3.663 + 2 × 4.227) × √1	**38.89 m**	Section 3
Band bars (2 of 8 mm) 5 % added to the length for laps and corners	n × φ² ÷ 162.2 × L	2 × (8² ÷ 162.2) × 40,850 ÷ 1000	**32.2 kg**	Engine rule
Number of stirrups	p ÷ 250 + 1	floor(38.89 × 1000 ÷ 250) + 1	**156**	Engine rule

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Cut length of a stirrup	Ls = 2 (A + E) + 12 φ + 2 × tail extra	2 × (65 + 25) + 12 × 6 + 2 × max(0; 75 − 10 × 6)	**282 mm**	Engine rule; cover 50 mm
Stirrups (6 mm)	n × φ² ÷ 162.2 × L	156 × (6² ÷ 162.2) × 300 ÷ 1000	**10.4 kg**	Engine rule
Steel in the parapet band	sum of the bars	32.24 + 10.39	**42.6 kg**	Engine rule
Concrete in the parapet band	V = p × width × thickness	38.89 × 0.115 × 0.075	**0.335 m³**	Engine rule
Shuttering of the parapet band	S = p × (width + 2 × thickness)	38.8867 × (0.115 + 2 × 0.075)	**10.30 m²**	Engine rule

Stair head-room (mumty) roof

STEP	FORMULA	WORKING	RESULT	SOURCE
Length of the head-room roof	lx = stair opening length + 2 × wall + overhang	3.3 + 2 × 0.115 + 0.3	**3.830 m**	Engine rule
Width of the head-room roof	ly = stair opening width + 2 × wall + overhang	2.1 + 2 × 0.115 + 0.3	**2.630 m**	Engine rule
Length of the ring beam	p = 2 (opening length + opening width + 4 × wall)	2 × (3.3 + 2.1 + 4 × 0.115)	**11.720 m**	Engine rule
Roof bars along the length: number	(ly − 100) ÷ s + 1	floor((2.63 × 1000 − 100) ÷ 150) + 1	**17**	Engine rule
Roof bars along the length	n × φ² ÷ 162.2 × L	17 × (8² ÷ 162.2) × 3,800 ÷ 1000	**25.5 kg**	Engine rule
Roof bars along the width: number	(lx − 100) ÷ s + 1	floor((3.83 × 1000 − 100) ÷ 150) + 1	**25**	Engine rule
Roof bars along the width	n × φ² ÷ 162.2 × L	25 × (8² ÷ 162.2) × 2,600 ÷ 1000	**25.6 kg**	Engine rule
Ring beam bars (4 of 10 mm) 5 % added for laps	n × φ² ÷ 162.2 × L	4 × (10² ÷ 162.2) × 12,325 ÷ 1000	**30.4 kg**	Engine rule
Ring beam stirrups: number	p ÷ 150 + 1	floor(11.72 × 1000 ÷ 150) + 1	**79**	Engine rule
Cut length of a ring beam stirrup	Ls = 2 (A + E) + 12 φ + 2 × tail extra	2 × (180 + 180) + 12 × 6 + 2 × max(0; 75 − 10 × 6)	**822 mm**	Engine rule; cover 50 mm
Ring beam stirrups (6 mm)	n × φ² ÷ 162.2 × L	79 × (6² ÷ 162.2) × 825 ÷ 1000	**14.5 kg**	Engine rule
Steel in the head-room roof	sum of the bars	25.49 + 25.65 + 30.39 + 14.47	**96.0 kg**	Engine rule
Concrete in the head-room roof	V = lx × ly × t + p × 0.23 × 0.23	3.83 × 2.63 × 0.1 + 11.72 × 0.23 × 0.23	**1.627 m³**	Engine rule
Shuttering of the head-room roof The roof soffit, and the sides and bottom of the ring beam	S = lx × ly + 3 × p × 0.23	3.83 × 2.63 + 2 × 11.72 × 0.23 + 11.72 × 0.23	**18.16 m²**	Engine rule

Small RCC items: totals

ITEM	NUMBER	CONCRETE (M³)	STEEL (KG)	SHUTTERING (M²)
Lintels over doors and windows	37	1.608	182.8	27.64
Sunshades (chajjas)	23	1.164	94.8	19.67
Terrace parapet coping band	1	0.335	42.6	10.30
Stair head-room (mumty) roof	1	1.627	96.0	18.16
All small items	**62**	**4.735**	**416.2**	**75.77**

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Small RCC items: totals carried to the take-off

STEP	FORMULA	WORKING	RESULT	SOURCE
Concrete in the small RCC items	sum of the table	4.7348	**4.73 m³**	Engine rule
Steel in the small RCC items	sum of the table	416.2	**416.2 kg**	Engine rule
Shuttering of the small RCC items	sum of the table	75.77	**75.8 m²**	Engine rule

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11. Steel take-off

All the reinforcement of the building is added up here: by member family, then by bar diameter, then turned into the steel to buy and the binding wire.

Steel: how it is counted

STEP	FORMULA	WORKING	RESULT	SOURCE
Mass of a bar The weights in every section of this sheet use this mass	mass per metre = φ² ÷ 162.2 (φ in mm)		**for example 12 mm: 0.888 kg/m, 16 mm: 1.578 kg/m**	IS 1786:2008
Cut lengths	every bar length is taken up to the next 25 mm		**a 3,310 mm bar is weighed as 3,325 mm**	IS 2502:1963 cl. 5.1.1
Hooks, laps and cover Hooks of stirrups and ties follow the tail rule of Section 6	allowed for in the length of each bar where it is worked		**beams: Section 6; columns: Section 7; footings and plinth: Section 8; slabs: Section 9**	Engine rule
Stock length	bars over 6 mm are bought in 12 m lengths		**6 mm bar comes as a coil, cut and bent on site**	CPWD Delhi Analysis of Rates 2014, as quoted in the tool's research notes (item number not re-read)
Allowance for cutting waste Added to the net weight to give the steel to buy			**5 %**	CPWD Delhi Analysis of Rates 2014, as quoted in the tool's research notes (item number not re-read)
Binding wire An upper estimate from the usual rate of about 0.9 kg per 100 kg			**9 kg per tonne of steel**	NirmanShastra assumption

Corrections applied to the recorded bars

LEVEL	BEAMS	SLABS
Level 1	1.0000	0.9366
Roof	1.0000	1.0000

Steel by member family

Each bar line the model recorded (diameter, cut length, number) is weighed again here and the lines are added by family. Sections 6 to 10 show how the bars of the governing members were chosen; this table adds every member.

MEMBER	BAR LINES	AS RECORDED (KG)	AFTER CORRECTIONS (KG)	WORKED IN
Footings (or raft)	24	139.2	139.2	Section 8
Plinth beams	34	418.9	418.9	Section 8
Columns	76	1,345.3	1,345.3	Section 7
Floor beams	166	1,229.7	1,229.7	Section 6
Floor slabs	100	1,545.9	1,496.9	Section 9
Staircase	4	113.3	113.3	Section 9
Lintels	111	182.8	182.8	Section 10
Sunshades	46	94.8	94.8	Section 10

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Terrace parapet band	2	42.6	42.6	Section 10
Stair head-room roof	4	96.0	96.0	Section 10
All members	**567**	**5,208.6**	**5,159.6**	

Net steel

STEP	FORMULA	WORKING	RESULT	SOURCE
Steel in the building, net	sum of the families	139.2 + 418.9 + 1,345 + 1,230 + 1,497 + 113.3 + 182.8 + 94.81 + 42.62 + 96	**5,159.6 kg**	Engine rule

Steel to buy: the 8 mm bars worked

STEP	FORMULA	WORKING	RESULT	SOURCE
Net weight of 8 mm bars			**2,779.6 kg**	Section 11, steel by member family
Steel to buy, 8 mm	net × 1.05	2,779.6 × 1.05	**2,918.6 kg**	Engine rule
Mass per metre of 8 mm bar	φ² ÷ 162.2	8² ÷ 162.2	**0.395 kg/m**	IS 1786:2008
12 m lengths of 8 mm	ceil(steel to buy ÷ (mass per metre × 12))	ceil(2,918.6 ÷ (0.3946 × 12))	**617**	Engine rule

Steel by diameter

DIAMETER	NET (KG)	TO BUY, +5 % (KG)	12 M LENGTHS
6 mm	97.5	102	coil
8 mm	2,779.6	2,919	617
10 mm	351.2	369	50
12 mm	1,397.3	1,467	138
16 mm	229.2	241	13
20 mm	304.8	320	11
All sizes	**5,159.6**	**5,418**	**829**

Steel to buy and binding wire

STEP	FORMULA	WORKING	RESULT	SOURCE
Steel to buy, all sizes	net × 1.05	5,160 × 1.05	**5,418 kg**	Engine rule
Binding wire	steel ÷ 1000 × 9	5,160 ÷ 1000 × 9	**46.4 kg**	NirmanShastra assumption

6 sizes of bar in all. Bars are counted in whole 12 m lengths for each size separately.

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12. Concrete and shuttering by member

The concrete and shuttering of the columns and beams are worked here; the other members were worked in their own sections. The parts are then set side by side and added.

Column: concrete and shuttering of one column

STEP	FORMULA	WORKING	RESULT	SOURCE
Column worked			**Ground floor, edge, 300 × 350 mm**	Section 7
Level of the column base Measured from the ground level; the column starts on top of the footing	z = –founding depth + lean concrete + footing thickness	–1.5 + 0.1 + 350 ÷ 1000	**-1.050 m**	Engine rule
Concrete length of the column The column stops under the beam-and-slab of the storey above	L = top of slab – slab thickness – base	3.45 – 150 ÷ 1000 – -1.05	**4.350 m**	Engine rule
Concrete in the column	V = b × D × L	300 ÷ 1000 × 350 ÷ 1000 × 4.35	**0.4567 m³**	Engine rule
Part of it below the ground Concrete below ground level takes the richer mix of the foundation	min(L ; –base) × b × D	min(4.35; –-1.05) × 300 ÷ 1000 × 350 ÷ 1000	**0.1102 m³**	Engine rule
Shuttering of the column	S = 2 (b + D) × L	2 × (300 + 350) ÷ 1000 × 4.35	**5.655 m²**	Engine rule

Columns: concrete and shuttering

STOREY	TYPE	PIECES	B × D (MM)	LENGTH (M)	CONCRETE EACH (M³)	CONCRETE (M³)	SHUTTERING (M²)
Ground floor	corner	4	300 × 300	4.35	0.391	1.566	20.88
Ground floor	edge	2	300 × 350	4.35	0.457	0.913	11.31
Ground floor	edge	4	350 × 300	4.35	0.457	1.827	22.62
Ground floor	interior	2	300 × 350	4.35	0.457	0.913	11.31
Floor 1	corner	4	300 × 300	2.85	0.256	1.026	13.68
Floor 1	edge	2	300 × 350	2.85	0.299	0.598	7.41
Floor 1	edge	4	350 × 300	2.85	0.299	1.197	14.82
Floor 1	interior	2	300 × 350	2.85	0.299	0.598	7.41
All columns		**24**				**8.640**	**109.44**

Columns: totals

STEP	FORMULA	WORKING	RESULT	SOURCE
Concrete in the columns below the ground	sum of the table	1.26	**1.260 m³**	Engine rule
Concrete in the columns above the ground	sum of the table	7.38	**7.380 m³**	Engine rule
Shuttering of the columns	sum of the table	109.44	**109.44 m²**	Engine rule

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Beam: concrete and shuttering of one beam

STEP	FORMULA	WORKING	RESULT	SOURCE
Beam worked			**Level 1, along the length, span 3.66 m, depth 350 mm**	Section 6
Column width along the beam, mean of the two ends	a = (c0 + c1) ÷ 2	(300 + 350) ÷ 2	**325 mm**	Section 7
Clear length of the beam	L – a	3.663 – 325 ÷ 1000	**3.338 m**	Engine rule
Depth of the beam below the slab The part within the slab is counted with the slab	(D – slab thickness)	(350 – 150) ÷ 1000	**0.200 m**	Engine rule
Concrete in the beam The correction is the floor-area correction of Section 3	V = b × depth below slab × clear length × correction	230 ÷ 1000 × 0.2 × 3.3382 × 1	**0.1536 m³**	Engine rule
Shuttering of the beam Soffit and two sides	S = (b + 2 × depth below slab) × clear length × correction	(230 ÷ 1000 + 2 × 0.2) × 3.338 × 1	**2.103 m²**	Engine rule

Floor beams: concrete and shuttering

SLAB LEVEL	TYPE	DEPTH D (MM)	PIECES	CLEAR LENGTH (M)	CONCRETE (M³)	SHUTTERING (M²)
Level 1	Edge beam	350	4	13.35	0.614	8.41
Level 1	Edge beam	375	2	6.63	0.343	4.51
Level 1	Inner beam	350	3	10.09	0.464	6.36
Level 1	Edge beam	400	4	15.61	0.897	11.39
Level 1	Inner beam	400	4	15.61	0.897	11.39
Roof	Edge beam	300	6	19.98	0.689	10.59
Roof	Inner beam	300	3	10.09	0.348	5.35
Roof	Edge beam	350	4	15.61	0.718	9.83
Roof	Inner beam	375	4	15.61	0.808	10.61
All beams			**34**	**122.57**	**5.779**	**78.44**

Concrete and shuttering include the correction of each floor to the area you gave. The plinth beams are counted in Section 8.

Floor beams: totals

STEP	FORMULA	WORKING	RESULT	SOURCE
Concrete in the floor beams	sum of the table	5.779	**5.779 m³**	Engine rule
Shuttering of the floor beams	sum of the table	78.44	**78.44 m²**	Engine rule

Concrete, steel and shuttering by part

Each figure is carried from the section that worked it: Section 8 (footings, plinth beams), Section 9 (slabs, staircase), Section 10 (balconies, small items), Section 11 (steel) and the two tables above.

PART	PIECES	CONCRETE (M³)	STEEL (KG)	SHUTTERING (M²)
Footings (or raft)	12	4.72	139	8.8
Plinth beams	17	4.77	419	55.5
Columns	24	8.64	1,345	109.4
Floor beams	34	5.78	1,230	78.4

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Slabs	12	26.83	1,497	149.7
Staircase	2	3.03	113	29.0
Lintels, sunshades, parapet band, stair head-room	62	4.73	416	75.8
Reinforced concrete total		**58.51**	**5,160**	**506.7**

Steel here is the bar weight before the cutting waste. Lean concrete under the footings (M7.5) is 2.48 m³ and is not part of the total.

Totals for the structure

STEP	FORMULA	WORKING	RESULT	SOURCE
Concrete below the ground Takes the mix of the foundations (Section 13)	footings + plinth beams + columns below ground	4.72 + 4.767 + 1.26	**10.75 m³**	Engine rule
Concrete above the ground Takes the mix of the superstructure (Section 13)	columns above + beams + slabs + staircase + small items + balconies	7.38 + 5.779 + 26.83 + 3.034 + 4.735 + 0	**47.76 m³**	Engine rule
Concrete in the whole structure	below + above	10.75 + 47.76	**58.51 m³**	Engine rule
Shuttering in the whole structure	sum of the parts	506.7	**506.7 m²**	Engine rule
Steel in the whole structure, net	sum of the parts	5,160	**5,160 kg**	Engine rule

The excavation and the lean concrete are in Section 8; the cement, sand and aggregate are in Section 13.

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13. Mixes and materials

The cement, sand and aggregate in a cubic metre of each grade are found first; the concrete of each mix, from the sections before, then gives the quantities to order.

How the mixes are taken

STEP	FORMULA	WORKING	RESULT	SOURCE
Concrete of M20 or lower IS 456 allows a nominal mix up to M20. The quantities per m³ are the CPWD figures, not the proportions of IS 456 Table 9	nominal mix: cement, sand and aggregate per m³ read from the CPWD tables		**used for the grades M7.5 to M20**	IS 456:2000 cl. 9.3; CPWD Delhi Analysis of Rates 2014, as quoted in the tool's research notes (item number not re-read)
Concrete of M25 or higher IS 10262 itself asks for trial batches with the local materials; the figures here are for ordering, not a mix design	design mix by the absolute-volume method		**worked step by step below**	IS 10262:2009 cl. 4.1 to 4.6
Cement bag			**50 kg**	Trade practice
Site wastage on cement, sand and aggregate Spillage and over-break			**3 %**	NirmanShastra assumption
Cubic metre to cubic feet			**35.3147 cft**	Unit conversion
Square metre to square feet			**10.7639 sq ft**	Unit conversion

Mix per cubic metre of M25 concrete, foundations and below ground

Worked in full for the first design mix. The other design mixes use the same steps with their own grade and exposure.

STEP	FORMULA	WORKING	RESULT	SOURCE
Exposure condition of this concrete	from Section 2		**moderate**	IS 456:2000 Table 3
Largest free water-cement ratio allowed Reinforced concrete, moderate exposure			**0.50**	IS 456:2000 Table 5
Smallest cement content allowed			**300 kg/m³**	IS 456:2000 Table 5
Water-cement ratio assumed for M25 A typical figure for the grade. The strength curves of the standard are not used, and no target mean strength is worked out			**0.48**	NirmanShastra assumption
Water-cement ratio used The lower ratio is the stricter one	the lower of the two	min(0.5, 0.48)	**0.48**	IS 10262:2009 cl. 4.1
Water per m³ of concrete 186 kg is the Table 2 value for 20 mm aggregate. The 100 mm slump and 20 mm aggregate are NirmanShastra assumptions	Table 2 water × (1 + 3 % for each 25 mm of slump above 50 mm)	186 × (1 + 0.03 × (100 − 50) ÷ 25)	**197.2 kg**	IS 10262:2009 cl. 4.2 and Table 2

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Cement from the water-cement ratio	water ÷ w/c	197.2 ÷ 0.48	**410.8 kg/m³**	IS 10262:2009 cl. 4.3
Cement used The tool stops at 450 kg/m³. IS 456 cl. 8.2.4.2 allows more only with special consideration of cracking	the larger of this and the minimum, but not over the upper limit	min(450, max(410.8, 300))	**410.8 kg/m³**	IS 10262:2009 cl. 4.3; IS 456:2000 cl. 8.2.4.2 and Table 5
Volume of all the aggregate in 1 m³ of concrete Absolute volumes. The specific gravity of cement, 3.15, is the figure of the worked example in the standard	1 − (cement ÷ (3.15 × 1000) + water ÷ 1000)	1 − (410.8 ÷ (3.15 × 1000) + 197.2 ÷ 1000)	**0.672 m³**	IS 10262:2009 cl. 4.6
Share of the aggregate that is coarse 0.62 is the Table 3 value for 20 mm aggregate and zone II sand at a ratio of 0.50. Zone II sand is a NirmanShastra assumption	0.62 + 0.01 for each 0.05 the ratio is below 0.50	0.62 + 0.01 × (0.5 − 0.48) ÷ 0.05	**0.624**	IS 10262:2009 cl. 4.4 and Table 3
Coarse aggregate by mass Specific gravity 2.70 is a NirmanShastra assumption	volume × share × specific gravity × 1000	0.6724 × 0.624 × 2.7 × 1000	**1,133 kg**	IS 10262:2009 cl. 4.6
Sand by mass Specific gravity 2.65 is a NirmanShastra assumption	volume × (1 − share) × specific gravity × 1000	0.672 × (1 − 0.624) × 2.65 × 1000	**670 kg**	IS 10262:2009 cl. 4.6
Sand as bought (loose volume) Loose dry sand at 1,600 kg/m³ is a NirmanShastra assumption	mass ÷ bulk density	670 ÷ 1,600	**0.419 m³**	NirmanShastra assumption
Aggregate as bought (loose volume) Loose 20 mm aggregate at 1,500 kg/m³ is a NirmanShastra assumption	mass ÷ bulk density	1,133 ÷ 1,500	**0.755 m³**	NirmanShastra assumption
Mix per m³ of concrete	cement to the whole kg, sand and aggregate to 0.001 m³		**411 kg cement, 0.419 m³ sand, 0.755 m³ aggregate**	Engine rule

The three mixes

WHERE	GRADE	CEMENT (KG/M³)	SAND (M³/M³)	AGGREGATE (M³/M³)	MINIMUM CEMENT, TABLE 5 (KG/M³)
above ground	M20	400	0.425	0.850	300
foundations and below ground	M25	411	0.419	0.755	300
lean concrete under footings	M7.5	170	0.470	0.890	not applied

The lean concrete under the footings is plain concrete, so the Table 5 minimum for reinforced concrete is not applied to it. M20 above ground: CPWD DAR 2014 item 4.1.2, nominal mix 1:1.5:3. M25 foundations and below ground: IS 10262:2009 design mix, w/c 0.48, water 197 L, 20 mm aggregate. M7.5 lean concrete under footings: CPWD DAR 2014 item 4.1.8, nominal mix 1:4:8.

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Nominal mixes against IS 456 Table 9

Table 9 limits the dry aggregate for each 50 kg bag of cement. The check turns the sand and aggregate of each nominal mix back into kilograms.

STEP	FORMULA	WORKING	RESULT	SOURCE
Dry aggregate per 50 kg of cement, M20 Uses the bulk densities assumed above, so this is a plausibility check	(sand × bulk density + aggregate × bulk density) ÷ (cement ÷ 50)	(0.425 × 1,600 + 0.85 × 1,500) ÷ (400 ÷ 50)	**244 kg**	NirmanShastra assumption
Most dry aggregate per 50 kg of cement, M20			**250 kg**	IS 456:2000 Table 9
M20 mix against Table 9	dry aggregate ≤ most allowed		**within the limit**	IS 456:2000 Table 9
Dry aggregate per 50 kg of cement, M7.5 Uses the bulk densities assumed above, so this is a plausibility check	(sand × bulk density + aggregate × bulk density) ÷ (cement ÷ 50)	(0.47 × 1,600 + 0.89 × 1,500) ÷ (170 ÷ 50)	**614 kg**	NirmanShastra assumption
Most dry aggregate per 50 kg of cement, M7.5			**625 kg**	IS 456:2000 Table 9
M7.5 mix against Table 9	dry aggregate ≤ most allowed		**within the limit**	IS 456:2000 Table 9

Cement, sand and aggregate before wastage, by mix

WHERE	CONCRETE (M³)	CEMENT (KG)	SAND (M³)	AGGREGATE (M³)
M20 above ground	47.76	19,104	20.30	40.60
M25 foundations and below ground	10.75	4,417	4.50	8.11
M7.5 lean concrete under footings	2.48	422	1.17	2.21
All concrete	**60.99**	**23,943**	**25.97**	**50.92**

Cement, sand and aggregate to order

STEP	FORMULA	WORKING	RESULT	SOURCE
Concrete of M20, above ground			**47.76 m³**	Section 12
Concrete of M25, foundations and below ground			**10.75 m³**	Section 12
Concrete of M7.5, lean concrete under footings			**2.48 m³**	Section 8
Cement before wastage	(Σ concrete × cement per m³) ÷ 50	(47.76 × 400 + 10.75 × 411 + 2.482 × 170) ÷ 50	**478.9 bags**	Engine rule
Cement to order	bags × (1 + wastage)	478.9 × 1.03	**493 bags**	NirmanShastra assumption
Sand before wastage	Σ concrete × sand per m³	47.76 × 0.425 + 10.75 × 0.419 + 2.482 × 0.47	**25.97 m³**	Engine rule
Sand to order	m³ × (1 + wastage)	25.97 × 1.03	**26.75 m³**	NirmanShastra assumption
Sand to order, in cubic feet	m³ × 35.3147	26.75 × 35.31	**945 cft**	Unit conversion
Aggregate before wastage	Σ concrete × aggregate per m³	47.76 × 0.85 + 10.75 × 0.755 + 2.482 × 0.89	**50.92 m³**	Engine rule
Aggregate to order	m³ × (1 + wastage)	50.92 × 1.03	**52.45 m³**	NirmanShastra assumption
Aggregate to order, in cubic feet	m³ × 35.3147	52.45 × 35.31	**1,852 cft**	Unit conversion

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Shuttering, excavation, steel and binding wire

STEP	FORMULA	WORKING	RESULT	SOURCE
Shuttering to order	area × 10.7639	506.7 × 10.764	**5,454 sq ft**	Unit conversion
Excavation for the foundation pits Volume from Section 8	volume × 35.3147	124.71 × 35.315	**4,404 cft**	Unit conversion
Reinforcement steel to buy			**5,418 kg**	Section 11
Binding wire			**46.4 kg**	Section 11

The buy list

MATERIAL	QUANTITY	UNIT	WORKED IN
Cement (50 kg bags)	493	bags	this section
Sand	945	cft	this section
Coarse aggregate	1,852	cft	this section
Reinforcement steel Fe500D	5,418	kg	Section 11
Binding wire	46.4	kg	Section 11
Shuttering (contact area)	5,454	sq ft	Sections 8 to 12
Excavation	4,404	cft	Section 8

The buy list of the report, rebuilt from the sections named.

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14. Other figures of the report

The report also prints ranges, per-square-metre figures, a comparison with built houses, the frame at a glance, the checks, the warnings, the assumptions and a list of what is not counted. Each is worked or placed here.

Area, steel per m² and concrete per m²

STEP	FORMULA	WORKING	RESULT	SOURCE
Built-up area in square feet	m² × 10.7639	185.81 × 10.764	**2,000 sq ft**	Unit conversion
Roofed floor area	built-up area + open parking level	185.8 + 0	**185.8 m²**	Engine rule
Steel per m² of floor Bar weight before the cutting waste	net steel ÷ roofed area	5,160 ÷ 185.8	**27.8 kg/m²**	Engine rule
Concrete per m² of floor	concrete ÷ roofed area	58.51 ÷ 185.8	**0.315 m³/m²**	Engine rule

The range under each total: concrete worked

The same two products are worked for the other three totals in the table below.

STEP	FORMULA	WORKING	RESULT	SOURCE
Where the range factors come from The model designs to the code minimum; built houses usually use more, so the high factors are larger than the low ones	the real figure is the figure shown × a factor from the low to the high one		**concrete 0.92 to 1.40, cement 0.92 to 1.40, shuttering 0.85 to 1.25, steel 0.90 to 1.60 (1.65 with an open parking level or balconies)**	NirmanShastra assumption: set from the published range of built houses and one Bill of Quantities; not a code value
Lowest likely concrete	figure × low factor	58.51 × 0.92	**54 m³**	NirmanShastra assumption: set from the published range of built houses and one Bill of Quantities; not a code value
Highest likely concrete	figure × high factor	58.51 × 1.4	**82 m³**	NirmanShastra assumption: set from the published range of built houses and one Bill of Quantities; not a code value
Concrete: per cent below the figure shown	(1 – low factor) × 100, to the whole number	(1 – 0.92) × 100	**8 %**	Engine rule
Concrete: per cent above the figure shown	(high factor – 1) × 100, to the whole number	(1.4 – 1) × 100	**40 %**	Engine rule

Range under each total

TOTAL	FIGURE SHOWN	LOW FACTOR	HIGH FACTOR	RANGE	IN THE REPORT AS
Concrete	59 m³	0.92	1.40	54 to 82 m³	8 % below, 40 % above
Steel to buy	5,418 kg	0.90	1.60	4,876 to 8,668 kg	10 % below, 60 % above
Cement	493 bags	0.92	1.40	454 to 691 bags	8 % below, 40 % above
Shuttering	5,454 sq ft	0.85	1.25	4,636 to 6,818 sq ft	15 % below, 25 % above

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This report against buildings that were built

STEP	FORMULA	WORKING	RESULT	SOURCE
Class of building 2 storeys in the frame	up to 4 storeys, or 5 to 12 storeys		**up to four storeys**	GKSPL, Building the Baseline (v1, March 2026), as reported by Conserve Consultants; not re-read
Steel per m² of real buildings of this class Published range; the sample size of each class is not published			**31 to 62 kg**	GKSPL, Building the Baseline (v1, March 2026), as reported by Conserve Consultants; not re-read
Concrete per m² of real buildings of this class			**0.36 to 0.44 m³**	GKSPL, Building the Baseline (v1, March 2026), as reported by Conserve Consultants; not re-read
Steel of real buildings of your floor area, low	range per m² × roofed area	31 × 185.8	**5,760 kg**	GKSPL, Building the Baseline (v1, March 2026), as reported by Conserve Consultants; not re-read
Steel of real buildings of your floor area, high	range per m² × roofed area	62 × 185.8	**11,520 kg**	GKSPL, Building the Baseline (v1, March 2026), as reported by Conserve Consultants; not re-read
Concrete of real buildings of your floor area, low	range per m² × roofed area	0.36 × 185.8	**66.9 m³**	GKSPL, Building the Baseline (v1, March 2026), as reported by Conserve Consultants; not re-read
Concrete of real buildings of your floor area, high	range per m² × roofed area	0.44 × 185.8	**81.8 m³**	GKSPL, Building the Baseline (v1, March 2026), as reported by Conserve Consultants; not re-read

The study range is an outside figure that the tool only multiplies by your floor area. It is not a code value and not a prediction for your house.

The frame at a glance

ITEM IN THE REPORT	VALUE	WORKED IN
Footprint	11.0 × 8.5 m	Section 3
Column grid	3 × 2 bays	Section 3
Spans	3.66 × 4.23 m	Section 3
Storey height	3.0 m	Section 3
Plinth above ground	0.45 m	Section 3
Founding depth	1.5 m	Section 2
Steel per m²	27.8 kg	this section
Concrete per m²	0.315 m³	this section
Wind speed used	47 m/s	Section 2
Which lateral force is the larger	earthquake, in both directions	Section 5

The checks printed in the report, and where they are worked

CHECK IN THE REPORT	STATUS	WORKED IN	NOTE
Concrete grade against exposure	pass	Sections 2 and 13	Grade, minimum cement and water-cement ratio come from IS 456 Table 5.
Reinforcement grade	pass	Section 2	Fe 500D is assumed throughout. The tool follows IS 13920:1993; IS 13920:2016 is the edition now in force.
Ductile detailing	advisory	Sections 6 and 7	The ductile rules followed are those of IS 13920:1993. The confining steel of the columns is not checked by the model (Section 7 shows the comparison).

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Foundation	pass	Section 8	The footing sizes follow the bearing capacity assumed for the ground class.
Nominal cover	advisory	Section 2	The covers used in the working are listed in Section 2.
Wind load check	pass	Section 5	The tool follows IS 875 (Part 3):1987. IS 875 (Part 3):2015 is the edition now in force.

Figures behind the warnings

STEP	FORMULA	WORKING	RESULT	SOURCE
Steel per m² of floor The tool warns when this is over 55 or under 22 kg/m²			**27.8 kg/m²**	this section

The warnings printed in the report

This run raised no warning.

The assumptions printed in the report, and where each is worked

ASSUMPTION	WORKED IN
Layout	Section 3
Seismic zone	Section 2
Type of frame	Sections 5 to 7
Concrete grades	Sections 2 and 13
Foundation	Sections 2 and 8
Loads	Section 4
Slab, beams and columns	Sections 3, 6, 7 and 9
Steel supply	Section 11
Small items	Section 10
Cement, sand and aggregate	Section 13
Wind	Section 5
What is not analysed	limits at the start of this sheet

Not counted in the report

ITEM
Brick or block masonry, plaster, flooring, doors, windows, painting, waterproofing
Lift shaft, basement, water tank, sump, septic tank, compound wall, boundary gate
Balconies, porticos, canopies and other cantilevers beyond the main grid
Backfilling, plinth filling, anti-termite treatment, curing water, scaffolding hire
Plumbing, electrical and finishing works

These items are outside the model: the sheet does not work them and the report does not include them.

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Reconciliation: the report against this sheet

The totals printed in the report, rebuilt from the working above. Every row must read the same on both sides. This shows that the report and this sheet agree with each other, which is a check of the arithmetic; it does not show that either one is right against a standard or against your site.

ITEM	IN THE REPORT	FROM THIS SHEET	MATCH
Storeys of the frame	2	2	Yes
Total built-up area	185.8 m²	185.8 m²	Yes
Footprint of the frame	92.90 m²	92.90 m²	Yes
Length of the plan	10.99 m	10.99 m	Yes
Width of the plan	8.45 m	8.45 m	Yes
Bays along the length	3	3	Yes
Bays along the width	2	2	Yes
Span along the length	3.66 m	3.66 m	Yes
Span along the width	4.23 m	4.23 m	Yes
Storey height	3.0 m	3.0 m	Yes
Plinth above ground	0.45 m	0.45 m	Yes
Founding depth	1.5 m	1.5 m	Yes
Basic wind speed	47 m/s	47 m/s	Yes
Earthquake base shear along x	91 kN	91 kN	Yes
Earthquake base shear along y	91 kN	91 kN	Yes
Wind base shear along x	61 kN	61 kN	Yes
Wind base shear along y	79 kN	79 kN	Yes
Wind pressure at the roof	1.33 kN/m²	1.33 kN/m²	Yes
Net wind pressure coefficient	0.95	0.95	Yes
Beams in the frame	34	34	Yes
Columns in the frame	24	24	Yes
Model version	qty-v2	qty-v2	Yes
Floors	G+1	G+1	Yes
Built-up area, sq ft and m²	2,000 sq ft, 185.8 m²	2,000 sq ft, 185.8 m²	Yes
Earthquake zone	Zone III	Zone III	Yes
Note on the zone	figures 1893, 2002, 1893, 2016	figures 1893, 2002, 1893, 2016	Yes
Concrete grades	M20 above, M25 below	M20 above, M25 below	Yes
Type of foundation	isolated	isolated	Yes
Total and range: concrete	58.5 m³, 54 to 82, 8 % below, 40 % above	58.5 m³, 54 to 82, 8 % below, 40 % above	Yes
Total and range: steel to buy	5,418 kg, 4,876 to 8,668, 10 % below, 60 % above	5,418 kg, 4,876 to 8,668, 10 % below, 60 % above	Yes
Total and range: cement	493 bags, 454 to 691, 8 % below, 40 % above	493 bags, 454 to 691, 8 % below, 40 % above	Yes

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Total and range: shuttering	5,454 sq ft, 4,636 to 6,818, 15 % below, 25 % above	5,454 sq ft, 4,636 to 6,818, 15 % below, 25 % above	Yes
Cement, 50 kg bags	493 bags	493 bags	Yes
Sand	945 cft, 26.7 m³	945 cft, 26.7 m³	Yes
Coarse aggregate	1,852 cft, 52.4 m³	1,852 cft, 52.4 m³	Yes
Reinforcement steel to buy, and bar weight	5,418 kg to buy, 5,160 kg of bars	5,418 kg to buy, 5,160 kg of bars	Yes
Binding wire	46.4 kg	46.4 kg	Yes
Shuttering	5,454 sq ft, 507 m²	5,454 sq ft, 507 m²	Yes
Excavation	4,404 cft, 124.7 m³	4,404 cft, 124.7 m³	Yes
Balcony slabs in the table of parts	absent	absent	Yes
Footings (or raft)	12 pieces, 4.72 m³, 139 kg, 8.8 m²	12 pieces, 4.72 m³, 139 kg, 8.8 m²	Yes
Plinth beams	17 pieces, 4.77 m³, 419 kg, 55.5 m²	17 pieces, 4.77 m³, 419 kg, 55.5 m²	Yes
Columns	24 pieces, 8.64 m³, 1,345 kg, 109.4 m²	24 pieces, 8.64 m³, 1,345 kg, 109.4 m²	Yes
Floor beams	34 pieces, 5.78 m³, 1,230 kg, 78.4 m²	34 pieces, 5.78 m³, 1,230 kg, 78.4 m²	Yes
Slabs	12 pieces, 26.83 m³, 1,497 kg, 149.7 m²	12 pieces, 26.83 m³, 1,497 kg, 149.7 m²	Yes
Staircase	2 pieces, 3.03 m³, 113 kg, 29.0 m²	2 pieces, 3.03 m³, 113 kg, 29.0 m²	Yes
Lintels, sunshades, parapet band, stair head-room	62 pieces, 4.73 m³, 416 kg, 75.8 m²	62 pieces, 4.73 m³, 416 kg, 75.8 m²	Yes
Reinforced concrete total (foot of the table of parts)	58.51 m³, 5,160 kg, 506.7 m²	58.51 m³, 5,160 kg, 506.7 m²	Yes
Lean concrete under the footings	2.48 m³	2.48 m³	Yes
Bar diameters in the table of steel	6, 8, 10, 12, 16, 20	6, 8, 10, 12, 16, 20	Yes
Steel of 6 mm bars	102 kg, coil	102 kg, coil	Yes
Steel of 8 mm bars	2,919 kg, 617 bars of 12 m	2,919 kg, 617 bars of 12 m	Yes
Steel of 10 mm bars	369 kg, 50 bars of 12 m	369 kg, 50 bars of 12 m	Yes
Steel of 12 mm bars	1,467 kg, 138 bars of 12 m	1,467 kg, 138 bars of 12 m	Yes
Steel of 16 mm bars	241 kg, 13 bars of 12 m	241 kg, 13 bars of 12 m	Yes
Steel of 20 mm bars	320 kg, 11 bars of 12 m	320 kg, 11 bars of 12 m	Yes
Foot of the table of steel by diameter	5,418 kg, 829 bars	5,418 kg, 829 bars	Yes
Number of mixes	3	3	Yes
Mix 1: where and grade	M20 above ground	M20 above ground	Yes
Mix 1: cement, sand and aggregate per m³	400 kg, 0.43 m³, 0.85 m³	400 kg, 0.43 m³, 0.85 m³	Yes
Mix 1: how it was found	figures 2014, 4.1, 2, 1, 1.5, 3	figures 2014, 4.1, 2, 1, 1.5, 3	Yes
Mix 2: where and grade	M25 foundations and below ground	M25 foundations and below ground	Yes
Mix 2: cement, sand and aggregate per m³	411 kg, 0.42 m³, 0.76 m³	411 kg, 0.42 m³, 0.76 m³	Yes
Mix 2: how it was found	figures 10262, 2009, 0.48, 197, 20	figures 10262, 2009, 0.48, 197, 20	Yes
Mix 3: where and grade	M7.5 lean concrete under footings	M7.5 lean concrete under footings	Yes
Mix 3: cement, sand and aggregate per m³	170 kg, 0.47 m³, 0.89 m³	170 kg, 0.47 m³, 0.89 m³	Yes
Mix 3: how it was found	figures 2014, 4.1, 8, 1, 4, 8	figures 2014, 4.1, 8, 1, 4, 8	Yes

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Rows in the column schedule	8	8	Yes
Columns: Ground floor, corner, 300 x 300 mm, 4-16	4 pieces, 0.89 %, ties 8 @ 75/150	4 pieces, 0.89 %, ties 8 @ 75/150	Yes
Columns: Ground floor, edge, 300 x 350 mm, 4-20	2 pieces, 1.20 %, ties 8 @ 75/150	2 pieces, 1.20 %, ties 8 @ 75/150	Yes
Columns: Ground floor, edge, 350 x 300 mm, 8-12	4 pieces, 0.86 %, ties 8 @ 75/150	4 pieces, 0.86 %, ties 8 @ 75/150	Yes
Columns: Ground floor, interior, 300 x 350 mm, 4-20	2 pieces, 1.20 %, ties 8 @ 75/150	2 pieces, 1.20 %, ties 8 @ 75/150	Yes
Columns: First floor, corner, 300 x 300 mm, 8-12	4 pieces, 1.01 %, ties 8 @ 75/150	4 pieces, 1.01 %, ties 8 @ 75/150	Yes
Columns: First floor, edge, 300 x 350 mm, 8-16	2 pieces, 1.53 %, ties 8 @ 75/150	2 pieces, 1.53 %, ties 8 @ 75/150	Yes
Columns: First floor, edge, 350 x 300 mm, 8-12	4 pieces, 0.86 %, ties 8 @ 75/150	4 pieces, 0.86 %, ties 8 @ 75/150	Yes
Columns: First floor, interior, 300 x 350 mm, 4-20	2 pieces, 1.20 %, ties 8 @ 75/150	2 pieces, 1.20 %, ties 8 @ 75/150	Yes
Rows in the beam schedule	10	10	Yes
Beams: First floor, edge beam, 230 x 350 mm	4 pieces, bars bottom 3-12, top 2-12 + 3-12; stirrups 8 @ 100/150	4 pieces, bars bottom 3-12, top 2-12 + 3-12; stirrups 8 @ 100/150	Yes
Beams: First floor, edge beam, 230 x 375 mm	2 pieces, bars bottom 2-12, top 2-12 + 3-12; stirrups 8 @ 100/150	2 pieces, bars bottom 2-12, top 2-12 + 3-12; stirrups 8 @ 100/150	Yes
Beams: First floor, inner beam, 230 x 350 mm	2 pieces, bars bottom 3-12, top 2-12 + 2-12; stirrups 8 @ 100/150	2 pieces, bars bottom 3-12, top 2-12 + 2-12; stirrups 8 @ 100/150	Yes
Beams: First floor, inner beam, 230 x 350 mm	1 pieces, bars bottom 3-12, top 2-12 + 3-12; stirrups 8 @ 100/150	1 pieces, bars bottom 3-12, top 2-12 + 3-12; stirrups 8 @ 100/150	Yes
Beams: First floor, edge beam, 230 x 400 mm	4 pieces, bars bottom 4-12, top 2-12 + 4-12; stirrups 8 @ 100/175	4 pieces, bars bottom 4-12, top 2-12 + 4-12; stirrups 8 @ 100/175	Yes
Beams: First floor, inner beam, 230 x 400 mm	4 pieces, bars bottom 4-12, top 2-12 + 4-12; stirrups 8 @ 100/175	4 pieces, bars bottom 4-12, top 2-12 + 4-12; stirrups 8 @ 100/175	Yes
Beams: Roof, edge beam, 230 x 300 mm	6 pieces, bars bottom 2-12, top 2-12 + 1-12; stirrups 8 @ 100/125	6 pieces, bars bottom 2-12, top 2-12 + 1-12; stirrups 8 @ 100/125	Yes
Beams: Roof, inner beam, 230 x 300 mm	3 pieces, bars bottom 3-12, top 2-12 + 2-12; stirrups 8 @ 100/125	3 pieces, bars bottom 3-12, top 2-12 + 2-12; stirrups 8 @ 100/125	Yes
Beams: Roof, edge beam, 230 x 350 mm	4 pieces, bars bottom 3-12, top 2-12 + 2-12; stirrups 8 @ 100/150	4 pieces, bars bottom 3-12, top 2-12 + 2-12; stirrups 8 @ 100/150	Yes
Beams: Roof, inner beam, 230 x 375 mm	4 pieces, bars bottom 4-12, top 2-12 + 3-12; stirrups 8 @ 100/150	4 pieces, bars bottom 4-12, top 2-12 + 3-12; stirrups 8 @ 100/150	Yes
Smaller items listed	Lintels over doors and windows; Sunshades (chajjas); Terrace parapet coping band; Stair head-room (mumty) roof	Lintels over doors and windows; Sunshades (chajjas); Terrace parapet coping band; Stair head-room (mumty) roof	Yes
Lintels over doors and windows	37 pieces, 1.61 m³, 183 kg	37 pieces, 1.61 m³, 183 kg	Yes
Lintels over doors and windows: basis	figures 150, 200, 1.2, 3.6, 13, 2	figures 150, 200, 1.2, 3.6, 13, 2	Yes
Sunshades (chajjas)	23 pieces, 1.16 m³, 95 kg	23 pieces, 1.16 m³, 95 kg	Yes

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Sunshades (chajjas): basis	figures 450, 75, 8, 150, 6, 200	figures 450, 75, 8, 150, 6, 200	Yes
Terrace parapet coping band	1 pieces, 0.34 m³, 43 kg	1 pieces, 0.34 m³, 43 kg	Yes
Terrace parapet coping band: basis	figures 115, 75, 2, 8, 6, 250	figures 115, 75, 2, 8, 6, 250	Yes
Stair head-room (mumty) roof	1 pieces, 1.63 m³, 96 kg	1 pieces, 1.63 m³, 96 kg	Yes
Stair head-room (mumty) roof: basis	figures 100, 8, 150, 230, 230, 4, 10, 6, 150	figures 100, 8, 150, 230, 230, 4, 10, 6, 150	Yes
Footprint of the frame, one decimal	11.0 x 8.5 m	11.0 x 8.5 m	Yes
Founding depth, one decimal	1.5 m	1.5 m	Yes
Steel per m² and concrete per m²	27.8 kg, 0.315 m³	27.8 kg, 0.315 m³	Yes
Which lateral force is larger	earthquake	earthquake	Yes
Number of checks	6	6	Yes
Standards named beside the checks	IS 456:2000 cl 6.1, Table 5; IS 13920:1993 cl 5.3 (Amendment No. 2); IS 1786:2008; IS 13920:1993 cl 6 and 7; IS 1904:1986; IS 456 cl 34; IS 456:2000 cl 26.4, Table 16; IS 875 (Part 3):1987 cl 5; IS 1893 (Part 1) cl 6.2	IS 456:2000 cl 6.1, Table 5; IS 13920:1993 cl 5.3 (Amendment No. 2); IS 1786:2008; IS 13920:1993 cl 6 and 7; IS 1904:1986; IS 456 cl 34; IS 456:2000 cl 26.4, Table 16; IS 875 (Part 3):1987 cl 5; IS 1893 (Part 1) cl 6.2	Yes
Check: Concrete grade against exposure	pass; figures 20, 25	pass; figures 20, 25	Yes
Check: Reinforcement grade	pass; figures 500	pass; figures 500	Yes
Check: Ductile detailing	advisory; figures 135, 1.1, 13920, 2016, 1.4	advisory; figures 135, 1.1, 13920, 2016, 1.4	Yes
Check: Foundation	pass	pass	Yes
Check: Nominal cover	advisory; figures 50, 40, 25, 20, 456, 16	advisory; figures 50, 40, 25, 20, 456, 16	Yes
Check: Wind load check	pass; figures 47	pass; figures 47	Yes
Number of warnings	0	0	Yes
Number of assumptions	12	12	Yes
Assumption: Layout	figures 3, 2, 3.66, 4.23, 3, 0.45	figures 3, 2, 3.66, 4.23, 3, 0.45	Yes
Assumption: Seismic zone	figures 1893, 2002, 1893, 2016	figures 1893, 2002, 1893, 2016	Yes
Assumption: Type of frame	figures 13920, 1993, 7.4, 6, 1.1, 7.4, 8	figures 13920, 1993, 7.4, 6, 1.1, 7.4, 8	Yes
Assumption: Concrete grades	figures 20, 25, 456, 5, 500	figures 20, 25, 456, 5, 500	Yes
Assumption: Foundation	figures 150, 2, 1.5	figures 150, 2, 1.5	Yes
Assumption: Loads	figures 1.5, 2, 2.0, 2, 1.5, 2, 875, 230, 115, 15	figures 1.5, 2, 2.0, 2, 1.5, 2, 875, 230, 115, 15	Yes
Assumption: Slab, beams and columns	figures 150, 456, 23.2, 230, 456, 39.6	figures 150, 456, 23.2, 230, 456, 39.6	Yes
Assumption: Steel supply	figures 12, 6, 5, 5.22, 1, 9	figures 12, 6, 5, 5.22, 1, 9	Yes
Assumption: Small items	figures 37, 23, 1, 1	figures 37, 23, 1, 1	Yes
Assumption: Cement, sand and aggregate	figures 2014, 20, 10262, 3	figures 2014, 20, 10262, 3	Yes
Assumption: Wind	figures 875, 3, 47, 1.33, 2, 61, 79, 91, 91, 1893, 6.2	figures 875, 3, 47, 1.33, 2, 61, 79, 91, 91, 1893, 6.2	Yes
Assumption: What is not analysed	figures 1893, 1987, 875, 3	figures 1893, 1987, 875, 3	Yes
Items not counted	5 items	5 items	Yes
Built houses: class	buildings of up to four storeys	buildings of up to four storeys	Yes

SAMPLE
example house, not your project

Built houses: source named in the report	GKSPL, Building the Baseline: Embodied Carbon in India's Urban Housing, v1, March 2026 (26 residential buildings, from Bills of Quantities), as reported by Conserve Consultants, 29 April 2026.	GKSPL, Building the Baseline: Embodied Carbon in India's Urban Housing, v1, March 2026 (26 residential buildings, from Bills of Quantities), as reported by Conserve Consultants, 29 April 2026.	**Yes**
Built houses: this report per m²	27.8 kg, 0.31 m³	27.8 kg, 0.31 m³	**Yes**
Built houses: range per m²	31 to 62 kg, 0.36 to 0.44 m³	31 to 62 kg, 0.36 to 0.44 m³	**Yes**
Built houses: range for your floor area	5,760 to 11,520 kg, 66.9 to 81.8 m³	5,760 to 11,520 kg, 66.9 to 81.8 m³	**Yes**

Standards and references used in this sheet

DOCUMENT	TITLE	USED FOR
IS 456:2000	Plain and Reinforced Concrete: Code of Practice	Concrete grade and cover, load combinations, beam, column, slab and footing design, shear, minimum steel and detailing. The tool follows this edition; check the BIS catalogue for any later revision.
IS 875 (Part 1):1987	Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures: Dead Loads	Unit weights of concrete, masonry and plaster. The edition used.
IS 875 (Part 2):1987	Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures: Imposed Loads	Imposed loads on floors, roof and balconies; reduction on columns. The edition used.
IS 875 (Part 3):1987	Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures: Wind Loads	Basic wind speed, height factor, design pressure and wall pressure coefficients. The tool follows the 1987 edition; IS 875 (Part 3):2015 is now in force.
IS 1893 (Part 1):2002	Criteria for Earthquake Resistant Design of Structures: General Provisions and Buildings	Zone factor, response reduction, period, spectral acceleration, base shear and its distribution, load combinations. The tool follows the 2002 edition; IS 1893 (Part 1):2016 is now in force.
IS 13920:1993	Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces: Code of Practice	Ductile detailing of beams and columns in Zone III and above. The tool follows the 1993 edition; IS 13920:2016 is now in force and is the edition some wording of the report names.
SP 24:1983	Explanatory Handbook on Indian Standard Code of Practice for Plain and Reinforced Concrete (IS 456:1978)	The formula behind the design shear strength of concrete (IS 456 Table 19). SP 24 explains IS 456:1978, the earlier edition of the code.
SP 34:1987	Handbook on Concrete Reinforcement and Detailing	Cover to the beam reinforcement. The edition used.
IS 1786:2008	High Strength Deformed Steel Bars and Wires for Concrete Reinforcement: Specification	Mass per metre of reinforcing bars. The edition used.
IS 2502:1963	Code of Practice for Bending and Fixing of Bars for Concrete Reinforcement	Cut lengths rounded up to the next 25 mm. The edition used.
IS 10262:2009	Concrete Mix Proportioning: Guidelines	The design mix of concrete of M25 and above (Section 13). The tool follows the 2009 edition; IS 10262:2019 is now in force.
IS 1904:1986	Code of Practice for Design and Construction of Foundations in Soils: General Requirements	The soil pressure under footings and rafts (Section 8). The edition quoted by the tool.
CPWD Delhi Analysis of Rates 2014, Vol. 1	Central Public Works Department, Delhi Analysis of Rates	Cement, sand and aggregate in a cubic metre of nominal-mix concrete (M20 and below), the cutting waste on steel and the binding wire. Item numbers as found in the tool's research notes; not re-read against the published text.
GKSPL, March 2026	Building the Baseline: Embodied Carbon in India's Urban Housing, v1	The range of steel and concrete per m² of 26 built houses shown beside the report (Section 14). As reported by Conserve Consultants; not re-read.

This sheet shows the method and the arithmetic behind a planning-level quantity estimate. It lets a qualified person check the formulas and the working. It is not a structural design, a drawing or a certificate, and it does not replace the drawings and calculations that a licensed professional signs for your building.

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