**Sample Calculation of FR-CSTM**

The following example is given for beam DB-SF100-200 of the current study (SNo:36 in Table A1.)

The beam contains hooked end macro steel fibers of 1% volume fraction in concrete, and no web reinforcement is provided. Though the beam has no web reinforcement, calculations corresponding to the web reinforcement effect are also included in this example for better understanding by keeping reinforcement ratios *ρh* and *ρv* as zero.

**Step 1:** Input parameters

b=180mm, h= 500mm, d= 442.5mm, a= 500mm, lbs = 100mm, lb = 200mm, V/P = 0.5, ρl = 1.57%, ρh =0, ρv = 0, fy = 500 MPa, fyw = 420 MPa, = 1%, = 30mm, = 0.6mm, Type of steel fiber = Hooked end, fc’ = 43.7 MPa, Es= 200GPa.

**Step 2:** Calculate nodal height or depth of compression zone ‘c’

Neglecting the effect of compression reinforcement and substituting

; ; ; ;

c = 148.9 mm

**Step 3:** Calculation of θ and

**Step 4:** Calculation of geometric dimensions of the top node

**Step 5:** Contribution of aggregate interlock

Effective rebar ratio =

Average crack spacing

Length of delamination crack

Crack width at mid-height of CSC = 0.56 mm

The contribution of aggregate interlock on effective compressive strength of the cracked

portion of the strut is

Aggregate size (ag) taken as 10 mm

**Step 6:** Contribution of web reinforcement

Average strain in the vertical web reinforcement

Tensile force in the stirrups

Contribution of vertical web reinforcement =

Vertical force in horizontal web reinforcement due to dowel action

is the stress in horizontal web reinforcement assuming average strain at mid-height as

Therefore, ,

Contribution of horizontal web reinforcement =

**Step 7:** Contribution of fibers

Pull out the strength of fiber through bond =

Pull out the strength of fiber through end anchorages =

As ,

As ,

Tensile stress due to frictional bond behavior 1

Tensile stress due to end anchorages

The vertical component of fibers resistance

Contribution of steel fibers on effective compressive strength

**Step 8:** Calculation of strut efficiency factors

The efficiency factor of an uncracked portion of the strut

The efficiency factor of a cracked portion of the strut

**Step 9:** Forces transferred through the strut along its axis

Force transferred through an uncracked portion

Force transferred through a cracked portion

**Step 10:** Ultimate shear capacity

Experimentally observed shear capacity

Table A1. Comparison of experimental vs predicted results of steel fiber reinforced concrete beams

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S.NO | Reference | Specimen ID | a/d | b (mm) | d (mm) | h (mm) | a (mm) | ρl (%) | ρv (%) | ρh (%) | fy (Mpa) | Vf (%) | fc' (Mpa) | fyw (Mpa) | V*u,exp* (kN) | V*u,pred* (kN) | V*u,exp*/ V*u,pred* |
| 1 | [1] | B1 | 0.30 | 90 | 463 | 500 | 145 | 1.9 | 0.50 | 0.57 | 440 | 1 | 35.7 | 375 | 375 | 373 | 1.01 |
| 2 | B2 | 0.60 | 90 | 463 | 500 | 285 | 1.9 | 0.50 | 0.57 | 440 | 1 | 35.7 | 375 | 360 | 324 | 1.11 |
| 3 | B3 | 0.90 | 90 | 463 | 500 | 430 | 1.9 | 0.50 | 0.57 | 440 | 1 | 35.5 | 375 | 291 | 271 | 1.07 |
| 4 | B4 | 1.20 | 90 | 463 | 500 | 570 | 1.9 | 0.50 | 0.57 | 440 | 1 | 31.1 | 375 | 228 | 203 | 1.12 |
| 5 | B5 | 1.80 | 90 | 463 | 500 | 855 | 1.9 | 0.50 | 0.57 | 440 | 1 | 31.5 | 375 | 183 | 146 | 1.25 |
| 6 | B6 | 1.20 | 90 | 463 | 500 | 570 | 1.9 | 0.50 | 0.57 | 440 | 0 | 34.4 | 375 | 205 | 196 | 1.05 |
| 7 | B7 | 1.20 | 90 | 463 | 500 | 570 | 1.9 | 0.50 | 0.57 | 440 | 0.5 | 33.8 | 375 | 220 | 214 | 1.03 |
| 8 | B8 | 1.20 | 90 | 463 | 500 | 570 | 1.9 | 0.50 | 0.57 | 440 | 1.5 | 33.2 | 375 | 260 | 214 | 1.22 |
| 9 | B9 | 1.50 | 90 | 463 | 500 | 700 | 1.9 | 0.50 | 1.26 | 440 | 1 | 29.5 | 375 | 224 | 170 | 1.32 |
| 10 | [2] | F30-0.0-13 | 1.43 | 120 | 168 | 200 | 240 | 1.32 | 0.00 | 0.00 | 399 | 0 | 34.4 | 623 | 74 | 62 | 1.18 |
| 11 | F30-0.5-13 | 1.43 | 120 | 168 | 200 | 240 | 1.32 | 0.00 | 0.00 | 399 | 0.5 | 25.7 | 623 | 61 | 70 | 0.87 |
| 12 | F60-0.0-13 | 1.43 | 120 | 168 | 200 | 240 | 1.32 | 0.00 | 0.00 | 399 | 0 | 54.3 | 623 | 65 | 85 | 0.76 |
| 13 | F70-0.0-19 | 1.43 | 120 | 168 | 200 | 240 | 2.82 | 0.00 | 0.00 | 456 | 0 | 65.3 | 623 | 118 | 105 | 1.12 |
| 14 | F70-0.5-19 | 1.43 | 120 | 168 | 200 | 240 | 2.82 | 0.00 | 0.00 | 456 | 0.5 | 70.5 | 623 | 179 | 148 | 1.21 |
| 15 | F70-1.0-19 | 1.43 | 120 | 168 | 200 | 240 | 2.82 | 0.00 | 0.00 | 456 | 1 | 67.3 | 623 | 170 | 174 | 0.98 |
| 16 | F70-1.5-19 | 1.43 | 120 | 168 | 200 | 240 | 2.82 | 0.00 | 0.00 | 456 | 1.5 | 67.3 | 623 | 187 | 174 | 1.08 |
| 17 | F80-0.0-16 | 1.43 | 120 | 168 | 200 | 240 | 2.00 | 0.00 | 0.00 | 442 | 0 | 74.1 | 623 | 146 | 109 | 1.35 |
| 18 | F80-0.5-16 | 1.43 | 120 | 168 | 200 | 240 | 2.00 | 0.00 | 0.00 | 442 | 0.5 | 82.4 | 623 | 158 | 158 | 1.00 |
| 19 | F80-0.0-19 | 1.43 | 120 | 168 | 200 | 240 | 2.82 | 0.00 | 0.00 | 343 | 0 | 85.2 | 623 | 108 | 134 | 0.81 |
| 20 | F80-0.5-19 | 1.43 | 120 | 168 | 200 | 240 | 2.82 | 0.00 | 0.00 | 343 | 0.5 | 86.1 | 623 | 154 | 173 | 0.89 |
| 21 | [3] | WO-1/1 | 0.58 | 80 | 624 | 650 | 360 | 0.81 | 0.43 | 0.00 | 418 | 1 | 40 | 304 | 345 | 339 | 1.02 |
| 22 | [4] | D0-0.25 | 1.8 | 150 | 450 | 500 | 800 | 1.90 | 0.30 | 0.67 | 420 | 0 | 25.4 | 260 | 195 | 178 | 1.10 |
| 23 | D0-0.15 | 1.8 | 150 | 450 | 500 | 800 | 1.90 | 0.20 | 0.67 | 420 | 0 | 25.4 | 260 | 188 | 159 | 1.18 |
| 24 | D0-0.1 | 1.8 | 150 | 450 | 500 | 800 | 1.90 | 0.10 | 0.67 | 420 | 0 | 25.4 | 260 | 168 | 140 | 1.20 |
| 25 | D30-0.25 | 1.8 | 150 | 450 | 500 | 800 | 1.90 | 0.30 | 0.67 | 420 | 0.4 | 33.3 | 260 | 275 | 246 | 1.12 |
| 26 | D30-0.15 | 1.8 | 150 | 450 | 500 | 800 | 1.90 | 0.20 | 0.67 | 420 | 0.4 | 33.3 | 260 | 260 | 246 | 1.06 |
| 27 | D30-0.1 | 1.8 | 150 | 450 | 500 | 800 | 1.90 | 0.10 | 0.67 | 420 | 0.4 | 33.3 | 260 | 205 | 246 | 0.83 |
| 28 | D45-0.25 | 1.8 | 150 | 450 | 500 | 800 | 1.90 | 0.30 | 0.67 | 420 | 0.6 | 35 | 260 | 285 | 256 | 1.11 |
| 29 | D45-0.15 | 1.8 | 150 | 450 | 500 | 800 | 1.90 | 0.20 | 0.67 | 420 | 0.6 | 35 | 260 | 260 | 256 | 1.02 |
| 30 | D45-0.1 | 1.8 | 150 | 450 | 500 | 800 | 1.90 | 0.10 | 0.67 | 420 | 0.6 | 35 | 260 | 230 | 256 | 0.90 |
| 31 | D65-0.25 | 1.8 | 150 | 450 | 500 | 800 | 1.90 | 0.30 | 0.67 | 420 | 0.8 | 32.9 | 260 | 285 | 243 | 1.17 |
| 32 | D65-0.15 | 1.8 | 150 | 450 | 500 | 800 | 1.90 | 0.20 | 0.67 | 420 | 0.8 | 32.9 | 260 | 265 | 243 | 1.09 |
| 33 | D65-0.1 | 1.8 | 150 | 450 | 500 | 800 | 1.90 | 0.10 | 0.67 | 420 | 0.8 | 32.9 | 260 | 255 | 243 | 1.05 |
| 34 | Current study | DB-F0-200 | 1.13 | 180 | 442.5 | 500 | 500 | 1.57 | 0.00 | 0.00 | 500 | 0 | 44.5 | 420 | 406 | 414 | 0.98 |
| 35 | DB-SF50-200 | 1.13 | 180 | 442.5 | 500 | 500 | 1.57 | 0.00 | 0.00 | 500 | 0.5 | 42.0 | 420 | 570 | 473 | 1.20 |
| **36** | **DB-SF100-200** | **1.13** | **180** | **442.5** | **500** | **500** | **1.57** | **0.00** | **0.00** | **500** | **1** | **43.7** | **420** | **607** | **565** | **1.08** |
| 37 | DB-SF150-200 | 1.13 | 180 | 442.5 | 500 | 500 | 1.57 | 0.00 | 0.00 | 500 | 1.5 | 47.6 | 420 | 620 | 626 | 0.99 |
| 38 | DB-S0.3-200 | 1.13 | 180 | 442.5 | 500 | 500 | 1.57 | 0.30 | 0.30 | 500 | 0 | 42.3 | 420 | 485 | 465 | 1.04 |
| 39 | DB-F0-100 | 1.13 | 180 | 442.5 | 500 | 500 | 1.57 | 0.00 | 0.00 | 500 | 0 | 44.5 | 420 | 364 | 308 | 1.18 |
| 40 | DB-SF100-100 | 1.13 | 180 | 442.5 | 500 | 500 | 1.57 | 0.00 | 0.00 | 500 | 1 | 43.7 | 420 | 542 | 461 | 1.18 |
| 41 | DB-SF150-100 | 1.13 | 180 | 442.5 | 500 | 500 | 1.57 | 0.00 | 0.00 | 500 | 1.5 | 47.6 | 420 | 622 | 513 | 1.21 |
| 42 | DB-S0.3-100 | 1.13 | 180 | 442.5 | 500 | 500 | 1.57 | 0.30 | 0.30 | 500 | 0 | 42.3 | 420 | 444 | 367 | 1.21 |

Table A2. Comparison of experimental vs predicted results of deep beams without web reinforcement

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S.NO | Ref. | Beam | a/d  (mm) | b  (mm) | d  (mm) | h  (mm) | a  (mm) | lb1  (mm) | lb2  (mm) | V/P | ρ*l*  (%) | fy  (MPa) | fc'  (MPa) | Vu  (kN) | CSTM  (kN) | Proposed  (kN) | 2PKT  (kN) |
| 1 | [5] | B0-1 | 1.96 | 203 | 389 | 457 | 762 | 89 | 89 | 1 | 0.98 | 370 | 23.6 | 121 | 80 | 134 | 120 |
| 2 |  | B0-3 | 1.96 | 203 | 389 | 457 | 762 | 89 | 89 | 1 | 0.98 | 370 | 23.5 | 128 | 80 | 133 | 134 |
| 3 |  | C0-1 | 1.57 | 203 | 389 | 457 | 610 | 89 | 89 | 1 | 0.98 | 370 | 24.7 | 174.3 | 115 | 185 | 185 |
| 4 |  | C0-3 | 1.57 | 203 | 389 | 457 | 610 | 89 | 89 | 1 | 0.98 | 370 | 23.6 | 166.9 | 111 | 179 | 175 |
| 5 | [6] | III-24a | 1.52 | 178 | 533 | 609 | 813 | 203 | 203 | 1 | 2.72 | 315 | 17.8 | 296.5 | 175 | 321 | 323 |
| 6 |  | III-24b | 1.52 | 178 | 533 | 609 | 813 | 203 | 203 | 1 | 2.72 | 315 | 20.6 | 303.2 | 195 | 356 | 312 |
| 7 |  | III-25a | 1.52 | 178 | 533 | 609 | 813 | 203 | 203 | 1 | 3.46 | 313 | 24.3 | 267.6 | 228 | 403 | 203 |
| 8 |  | III-25b | 1.52 | 178 | 533 | 609 | 813 | 203 | 203 | 1 | 3.46 | 313 | 17.2 | 289.8 | 176 | 316 | 287 |
| 9 |  | III-26a | 1.52 | 178 | 533 | 609 | 813 | 203 | 203 | 1 | 4.25 | 302 | 21.7 | 421.1 | 216 | 377 | 497 |
| 10 |  | III-26b | 1.52 | 178 | 533 | 609 | 813 | 203 | 203 | 1 | 4.25 | 302 | 20.6 | 396.6 | 208 | 363 | 452 |
| 11 |  | III-27a | 1.52 | 178 | 533 | 609 | 813 | 203 | 203 | 1 | 2.72 | 315 | 21.4 | 347.7 | 203 | 366 | 403 |
| 12 |  | III-27b | 1.52 | 178 | 533 | 609 | 813 | 203 | 203 | 1 | 2.72 | 315 | 22.9 | 356.6 | 214 | 384 | 407 |
| 13 |  | III-28a | 1.52 | 178 | 533 | 609 | 813 | 203 | 203 | 1 | 3.46 | 313 | 23.3 | 303.2 | 223 | 391 | 270 |
| 14 |  | III-28b | 1.52 | 178 | 533 | 609 | 813 | 203 | 203 | 1 | 3.46 | 313 | 22.4 | 341 | 215 | 381 | 348 |
| 15 |  | III-29a | 1.52 | 178 | 533 | 609 | 813 | 203 | 203 | 1 | 4.25 | 302 | 21.7 | 389.9 | 216 | 377 | 425 |
| 16 |  | III-29b | 1.52 | 178 | 533 | 609 | 813 | 203 | 203 | 1 | 4.25 | 302 | 25 | 436.6 | 240 | 416 | 498 |
| 17 | [7] | 1 | 1 | 190 | 270 | 320 | 270 | 75 | 100 | 1 | 2.07 | 465 | 32.4 | 388.5 | 209 | 303 | 462 |
| 18 |  | 2 | 1.48 | 190 | 270 | 320 | 400 | 75 | 100 | 1 | 2.07 | 465 | 32.4 | 260 | 131 | 201 | 296 |
| 19 |  | 3 | 2 | 190 | 270 | 320 | 540 | 75 | 100 | 1 | 2.07 | 465 | 32.4 | 147.2 | 84 | 135 | 134 |
| 20 | [8] | I-1 | 1.51 | 203 | 403 | 457 | 610 | 89 | 89 | 1 | 3.05 | 267 | 25.4 | 312.9 | 165 | 254 | 388 |
| 21 |  | I-2 | 1.51 | 203 | 403 | 457 | 610 | 89 | 89 | 1 | 3.05 | 267 | 23 | 310.7 | 154 | 238 | 398 |
| 22 |  | II-3 | 1.51 | 203 | 403 | 457 | 610 | 89 | 89 | 1 | 1.88 | 466 | 21.9 | 261.8 | 116 | 188 | 304 |
| 23 |  | II-4 | 1.51 | 203 | 403 | 457 | 610 | 89 | 89 | 1 | 1.88 | 466 | 26.4 | 312.9 | 134 | 214 | 397 |
| 24 |  | III-5 | 1.51 | 203 | 403 | 457 | 610 | 89 | 89 | 1 | 1.85 | 490 | 25.7 | 288.5 | 129 | 210 | 340 |
| 25 |  | III-6 | 1.51 | 203 | 403 | 457 | 610 | 89 | 89 | 1 | 1.85 | 490 | 25.6 | 290.7 | 129 | 207 | 346 |
| 26 |  | IV-7 | 1.51 | 203 | 403 | 457 | 610 | 89 | 89 | 1 | 1.86 | 443 | 24.1 | 290.8 | 126 | 203 | 366 |
| 27 |  | IV-8 | 1.51 | 203 | 403 | 457 | 610 | 89 | 89 | 1 | 1.86 | 443 | 24.9 | 304 | 130 | 208 | 395 |
| 28 |  | V-9 | 1.51 | 203 | 403 | 457 | 610 | 89 | 89 | 1 | 1.16 | 698 | 23.1 | 224 | 104 | 171 | 242 |
| 29 |  | 67 | 1.03 | 157 | 528 | 610 | 543 | 152 | 152 | 1 | 2.75 | 407 | 30.3 | 548 | 323 | 460 | 690 |
| 30 |  | 72 | 1.98 | 152 | 549 | 610 | 1087 | 152 | 152 | 1 | 2.71 | 384 | 24.8 | 196.9 | 112 | 221 | 222 |
| 31 |  | 61 | 2 | 156 | 542 | 610 | 1085 | 64 | 76 | 1 | 2.75 | 349 | 26.8 | 163.3 | 87 | 115 | 176 |
| 32 |  | 65 | 2.46 | 150 | 552 | 610 | 1359 | 152 | 152 | 1 | 2.82 | 374 | 27 | 112.4 | 85 | 141 | 132 |
| 33 | [9] | 0A0-44 | 1 | 102 | 305 | 356 | 305 | 102 | 102 | 1 | 1.94 | 422 | 20.5 | 139.5 | 127 | 155 | 142 |
| 34 |  | 0A0-48 | 1 | 102 | 305 | 356 | 305 | 102 | 102 | 1 | 1.94 | 422 | 20.9 | 136.1 | 129 | 157 | 133 |
| 35 |  | 0B0-49 | 1.21 | 102 | 305 | 356 | 368 | 102 | 102 | 1 | 1.94 | 422 | 21.7 | 149 | 109 | 136 | 185 |
| 36 |  | 0C0-50 | 1.5 | 102 | 305 | 356 | 457 | 102 | 102 | 1 | 1.94 | 422 | 20.7 | 115.7 | 79 | 104 | 142 |
| 37 |  | 0D0-47 | 2.08 | 102 | 305 | 356 | 635 | 102 | 102 | 1 | 1.94 | 422 | 19.5 | 73.4 | 46 | 65 | 91 |
| 38 | [10] | N960-l | 2.57 | 400 | 889 | 960 | 2289 | 100 | 100 | 1 | 1.2 | 385 | 34.2 | 366.6 | 154 | 291 | 433 |
| 39 |  | N960-h | 2.57 | 400 | 889 | 960 | 2289 | 100 | 100 | 1 | 2 | 385 | 34.2 | 386.1 | 157 | 319 | 417 |
| 40 | [11] | L5-100 | 0.53 | 160 | 935 | 1000 | 500 | 100 | 100 | 1 | 0.9 | 804 | 31.4 | 582.1 | 328 | 532 | 541 |
| 41 |  | L5-75 | 0.55 | 160 | 685 | 750 | 375 | 100 | 100 | 1 | 1.05 | 804 | 31.4 | 596.8 | 320 | 479 | 668 |
| 42 |  | L5-60 | 0.54 | 160 | 555 | 600 | 300 | 100 | 100 | 1 | 0.97 | 804 | 31.4 | 535.1 | 308 | 458 | 589 |
| 43 |  | L5-40 | 0.56 | 160 | 355 | 400 | 200 | 100 | 100 | 1 | 1.01 | 804 | 31.4 | 446.9 | 285 | 419 | 505 |
| 44 |  | L10-75 | 1.09 | 160 | 685 | 750 | 750 | 100 | 100 | 1 | 1.05 | 804 | 31.4 | 271.5 | 188 | 277 | 217 |
| 45 |  | L10-60 | 1.08 | 160 | 555 | 600 | 600 | 100 | 100 | 1 | 0.97 | 804 | 31.4 | 375.3 | 185 | 280 | 458 |
| 46 |  | L10-40 | 1.13 | 160 | 355 | 400 | 400 | 100 | 100 | 1 | 1.01 | 804 | 31.4 | 192.1 | 167 | 264 | 150 |
| 47 |  | UH5-100 | 0.53 | 160 | 935 | 1000 | 500 | 100 | 100 | 1 | 0.9 | 804 | 78.5 | 1029 | 611 | 1054 | 1132 |
| 48 |  | UH5-75 | 0.55 | 160 | 685 | 750 | 375 | 100 | 100 | 1 | 1.05 | 804 | 78.5 | 1010.4 | 596 | 959 | 1223 |
| 49 |  | UH5-60 | 0.54 | 160 | 555 | 600 | 300 | 100 | 100 | 1 | 0.97 | 804 | 78.5 | 823.2 | 577 | 921 | 864 |
| 50 |  | UH5-40 | 0.56 | 160 | 355 | 400 | 200 | 100 | 100 | 1 | 1.01 | 804 | 78.5 | 733 | 537 | 856 | 792 |
| 51 |  | UH10-100 | 1.07 | 160 | 935 | 1000 | 1000 | 100 | 100 | 1 | 0.9 | 804 | 78.5 | 769.3 | 367 | 589 | 1046 |
| 52 |  | UH10-75 | 1.09 | 160 | 685 | 750 | 750 | 100 | 100 | 1 | 1.05 | 804 | 78.5 | 338.1 | 352 | 543 | 227 |
| 53 | [12] | 1 | 0.5 | 300 | 400 | 450 | 200 | 100 | 100 | 1 | 2.14 | 458 | 23.2 | 853 | 455 | 763 | 972 |
| 54 |  | 5 | 1 | 300 | 400 | 450 | 400 | 100 | 100 | 1 | 2.14 | 458 | 29 | 632 | 348 | 597 | 708 |
| 55 |  | 9 | 1.5 | 300 | 400 | 450 | 600 | 100 | 100 | 1 | 2.14 | 458 | 22.9 | 284 | 174 | 329 | 227 |
| 56 |  | 13 | 1 | 300 | 400 | 450 | 400 | 100 | 100 | 1 | 2.14 | 458 | 32 | 661 | 376 | 641 | 734 |
| 57 |  | 24 | 0.5 | 300 | 400 | 450 | 200 | 100 | 100 | 1 | 2.14 | 702 | 79.9 | 1958 | 1068 | 1894 | 2428 |
| 58 |  | 25 | 1 | 300 | 400 | 450 | 400 | 100 | 100 | 1 | 2.14 | 702 | 76.4 | 1403 | 649 | 1142 | 1950 |
| 59 |  | 26 | 1.5 | 300 | 400 | 450 | 600 | 100 | 100 | 1 | 2.14 | 702 | 78.3 | 904 | 393 | 728 | 1175 |
| 60 |  | 27 | 2 | 300 | 400 | 450 | 800 | 100 | 100 | 1 | 2.14 | 702 | 77.8 | 752 | 255 | 481 | 1196 |
| 61 |  | 35 | 0.5 | 300 | 400 | 450 | 200 | 100 | 100 | 1 | 0.42 | 1330 | 25.3 | 588 | 398 | 638 | 576 |
| 62 |  | 38 | 1 | 300 | 400 | 450 | 400 | 100 | 100 | 1 | 0.42 | 1330 | 25.2 | 358 | 250 | 431 | 329 |
| 63 |  | 45 | 2.5 | 300 | 400 | 450 | 1000 | 100 | 100 | 1 | 2.14 | 750 | 97.2 | 345 | 209 | 391 | 473 |
| 64 | [13] | B-2 | 0.5 | 240 | 400 | 475 | 200 | 100 | 100 | 1 | 2.02 | 376 | 36.2 | 775 | 547 | 837 | 791 |
| 65 |  | B-6 | 1 | 240 | 400 | 475 | 400 | 100 | 100 | 1 | 2.02 | 376 | 31.3 | 525 | 321 | 493 | 593 |
| 66 |  | B-10-1 | 1.5 | 240 | 400 | 475 | 600 | 100 | 100 | 1 | 2.02 | 376 | 29.2 | 308 | 186 | 303 | 311 |
| 67 |  | B-10-2 | 1.5 | 240 | 400 | 475 | 600 | 100 | 100 | 1 | 2.02 | 376 | 23 | 351.5 | 155 | 256 | 460 |
| 68 |  | B-10.3-1 | 1.5 | 360 | 600 | 675 | 900 | 150 | 150 | 1 | 2.11 | 388 | 37.8 | 980 | 430 | 812 | 1313 |
| 69 |  | B-10.3-2 | 1.5 | 360 | 600 | 675 | 900 | 150 | 150 | 1 | 2.11 | 372 | 31.2 | 893.5 | 370 | 715 | 1233 |
| 70 |  | B-13-1 | 1.5 | 480 | 800 | 905 | 1200 | 200 | 200 | 1 | 2.07 | 398 | 31.6 | 1492.5 | 615 | 1194 | 1985 |
| 71 |  | B-13-2 | 1.5 | 480 | 800 | 905 | 1200 | 200 | 200 | 1 | 2.07 | 398 | 24 | 1128.5 | 489 | 980 | 1320 |
| 72 |  | B-14 | 1.5 | 600 | 1000 | 1105 | 1500 | 250 | 250 | 1 | 2.04 | 398 | 31 | 1984.5 | 910 | 1829 | 2381 |
| 73 |  | B15 | 1.5 | 720 | 1200 | 1305 | 1800 | 300 | 300 | 1 | 1.99 | 402 | 27 | 2695 | 1139 | 2369 | 3423 |
| 74 |  | B-16 | 1.5 | 840 | 1400 | 1505 | 2100 | 350 | 350 | 1 | 2.05 | 394 | 27.3 | 2987.5 | 1541 | 3258 | 3077 |
| 75 | [14] | 2DB35 | 1.1 | 80 | 314 | 350 | 345 | 53 | 53 | 1 | 1.25 | 469 | 27.4 | 85 | 86 | 79 | 89 |
| 76 |  | 2DB50 | 1.1 | 80 | 459 | 500 | 505 | 75 | 75 | 1 | 1.18 | 520 | 32.4 | 135.5 | 115 | 121 | 152 |
| 77 |  | 2DB70 | 1.1 | 80 | 650 | 700 | 715 | 105 | 105 | 1 | 1.33 | 520 | 24.8 | 155.5 | 124 | 141 | 171 |
| 78 |  | 2DB100 | 1.1 | 80 | 926 | 1000 | 1019 | 150 | 150 | 1 | 1.3 | 520 | 30.6 | 241.5 | 179 | 218 | 290 |
| 79 |  | 3DB35b | 1.1 | 80 | 314 | 350 | 345 | 53 | 53 | 1 | 1.25 | 469 | 27.4 | 85 | 86 | 79 | 89 |
| 80 |  | 3DB50b | 1.1 | 115 | 454 | 500 | 499 | 75 | 75 | 1 | 1.28 | 520 | 28.3 | 167 | 129 | 158 | 170 |
| 81 |  | 3DB70b | 1.1 | 160 | 642 | 700 | 706 | 105 | 105 | 1 | 1.22 | 522 | 28.7 | 360.5 | 201 | 298 | 433 |
| 82 |  | 3DB100b | 1.1 | 230 | 904 | 1000 | 994 | 150 | 150 | 1 | 1.2 | 555 | 29.3 | 672 | 352 | 566 | 780 |

Table A3. Comparison of experimental vs predicted results of deep beams with web reinforcement

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S.NO | Ref. | Beam | a/d | b  (mm) | d  (mm) | h  (mm) | a  (mm) | lb1  (mm) | lb2  (mm) | V/P | ρ*l*  (%) | fy  (MPa) | fc'  (MPa) | ρv  (%) | fyv  (MPa) | ρh  (%) | Vu  (kN) | CSTM  (kN) | Proposed (kN) | 2PKT  (kN) |
| 1 | [5] | B1-1 | 2 | 203 | 389 | 457 | 762 | 89 | 89 | 1 | 3.1 | 321 | 23.4 | 0.4 | 331 | 0 | 279 | 191 | 250 | 236 |
| 2 | B1-2 | 2 | 203 | 389 | 457 | 762 | 89 | 89 | 1 | 3.1 | 321 | 25.4 | 0.4 | 331 | 0 | 257 | 205 | 266 | 242 |
| 3 | B1-3 | 2 | 203 | 389 | 457 | 762 | 89 | 89 | 1 | 3.1 | 321 | 23.7 | 0.4 | 331 | 0 | 285 | 193 | 253 | 237 |
| 4 | B1-4 | 2 | 203 | 389 | 457 | 762 | 89 | 89 | 1 | 3.1 | 321 | 23.3 | 0.4 | 331 | 0 | 268 | 190 | 249 | 237 |
| 5 | B1-5 | 2 | 203 | 389 | 457 | 762 | 89 | 89 | 1 | 3.1 | 321 | 24.6 | 0.4 | 331 | 0 | 241 | 199 | 260 | 241 |
| 6 | B6-1 | 2 | 203 | 389 | 457 | 762 | 89 | 89 | 1 | 3.1 | 321 | 42.1 | 0.4 | 331 | 0 | 379 | 257 | 331 | 287 |
| 7 | C1-1 | 1.6 | 203 | 389 | 457 | 610 | 89 | 89 | 1 | 2.1 | 321 | 25.6 | 0.3 | 331 | 0 | 278 | 196 | 285 | 235 |
| 8 | C1-2 | 1.6 | 203 | 389 | 457 | 610 | 89 | 89 | 1 | 2.1 | 321 | 26.3 | 0.3 | 331 | 0 | 311 | 199 | 289 | 237 |
| 9 | C1-3 | 1.6 | 203 | 389 | 457 | 610 | 89 | 89 | 1 | 2.1 | 321 | 24 | 0.3 | 331 | 0 | 246 | 190 | 275 | 228 |
| 10 | C1-4 | 1.6 | 203 | 389 | 457 | 610 | 89 | 89 | 1 | 2.1 | 321 | 29 | 0.3 | 331 | 0 | 286 | 209 | 303 | 249 |
| 11 | D1-1 | 1.2 | 203 | 395 | 457 | 457 | 89 | 89 | 1 | 1.6 | 335 | 26.2 | 0.4 | 331 | 0 | 301 | 234 | 367 | 274 |
| 12 | D4-1 | 1.2 | 203 | 395 | 457 | 457 | 89 | 89 | 1 | 1.6 | 335 | 23.1 | 1.2 | 331 | 0 | 312 | 241 | 349 | 309 |
| 13 | D1-6 | 2 | 152 | 313 | 381 | 610 | 89 | 89 | 1 | 3.6 | 335 | 27.6 | 0.5 | 331 | 0 | 175 | 177 | 195 | 173 |
| 14 | [6] | III-30 | 1.5 | 178 | 533 | 609 | 813 | 203 | 203 | 1 | 4.2 | 302 | 25.4 | 0.5 | 326 | 0 | 478 | 349 | 522 | 447 |
| 15 | III-31 | 1.5 | 178 | 533 | 609 | 813 | 203 | 203 | 1 | 4.2 | 302 | 22.4 | 0.9 | 303 | 0 | 507 | 370 | 564 | 470 |
| 16 | [9] | 1A1-10 | 1 | 102 | 305 | 356 | 305 | 102 | 102 | 1 | 1.9 | 422 | 18.7 | 0.3 | 460 | 0.2 | 161 | 133 | 163 | 131 |
| 17 | 1A2-11 | 1 | 102 | 305 | 356 | 305 | 102 | 102 | 1 | 1.9 | 422 | 18 | 0.3 | 460 | 0.4 | 148 | 130 | 159 | 128 |
| 18 | 1A3-12 | 1 | 102 | 305 | 356 | 305 | 102 | 102 | 1 | 1.9 | 422 | 16.1 | 0.3 | 460 | 0.7 | 141 | 121 | 148 | 120 |
| 19 | 1A4-51 | 1 | 102 | 305 | 356 | 305 | 102 | 102 | 1 | 1.9 | 422 | 20.5 | 0.3 | 460 | 0.7 | 171 | 141 | 173 | 138 |
| 20 | 1A6-37 | 1 | 102 | 305 | 356 | 305 | 102 | 102 | 1 | 1.9 | 422 | 21.1 | 0.3 | 460 | 0.9 | 184 | 144 | 177 | 141 |
| 21 | 2A1-38 | 1 | 102 | 305 | 356 | 305 | 102 | 102 | 1 | 1.9 | 422 | 21.7 | 0.6 | 460 | 0.2 | 175 | 164 | 187 | 144 |
| 22 | 2A3-39 | 1 | 102 | 305 | 356 | 305 | 102 | 102 | 1 | 1.9 | 422 | 19.8 | 0.6 | 460 | 0.4 | 171 | 156 | 179 | 138 |
| 23 | 2A4-40 | 1 | 102 | 305 | 356 | 305 | 102 | 102 | 1 | 1.9 | 422 | 20.3 | 0.6 | 460 | 0.7 | 172 | 158 | 183 | 140 |
| 24 | 2A6-41 | 1 | 102 | 305 | 356 | 305 | 102 | 102 | 1 | 1.9 | 422 | 19.1 | 0.6 | 460 | 0.9 | 162 | 153 | 175 | 136 |
| 25 | 3A1-42 | 1 | 102 | 305 | 356 | 305 | 102 | 102 | 1 | 1.9 | 422 | 18.4 | 1.2 | 460 | 0.2 | 161 | 148 | 168 | 141 |
| 26 | 3A3-43 | 1 | 102 | 305 | 356 | 305 | 102 | 102 | 1 | 1.9 | 422 | 19.2 | 1.2 | 460 | 0.4 | 173 | 154 | 174 | 145 |
| 27 | 3A4-45 | 1 | 102 | 305 | 356 | 305 | 102 | 102 | 1 | 1.9 | 422 | 20.8 | 1.2 | 460 | 0.7 | 179 | 166 | 187 | 153 |
| 28 | 3A6-46 | 1 | 102 | 305 | 356 | 305 | 102 | 102 | 1 | 1.9 | 422 | 19.9 | 1.2 | 460 | 0.9 | 168 | 159 | 181 | 149 |
| 29 | 1B1-01 | 1.2 | 102 | 305 | 356 | 368 | 102 | 102 | 1 | 1.9 | 422 | 22.1 | 0.2 | 460 | 0.2 | 148 | 130 | 157 | 128 |
| 30 | 1B3-29 | 1.2 | 102 | 305 | 356 | 368 | 102 | 102 | 1 | 1.9 | 422 | 20.1 | 0.2 | 460 | 0.4 | 144 | 123 | 148 | 122 |
| 31 | 1B4-30 | 1.2 | 102 | 305 | 356 | 368 | 102 | 102 | 1 | 1.9 | 422 | 20.8 | 0.2 | 460 | 0.7 | 140 | 126 | 152 | 124 |
| 32 | 1B6-31 | 1.2 | 102 | 305 | 356 | 368 | 102 | 102 | 1 | 1.9 | 422 | 19.5 | 0.2 | 460 | 0.9 | 153 | 121 | 146 | 120 |
| 33 | 1C1-14 | 1.5 | 102 | 305 | 356 | 457 | 102 | 102 | 1 | 1.9 | 422 | 19.2 | 0.2 | 460 | 0.2 | 119 | 103 | 118 | 101 |
| 34 | 1C3-02 | 1.5 | 102 | 305 | 356 | 457 | 102 | 102 | 1 | 1.9 | 422 | 21.9 | 0.2 | 460 | 0.4 | 123 | 111 | 127 | 107 |
| 35 | 1C4-15 | 1.5 | 102 | 305 | 356 | 457 | 102 | 102 | 1 | 1.9 | 422 | 22.7 | 0.2 | 460 | 0.7 | 131 | 113 | 130 | 109 |
| 36 | 1C6-16 | 1.5 | 102 | 305 | 356 | 457 | 102 | 102 | 1 | 1.9 | 422 | 21.8 | 0.2 | 460 | 0.9 | 122 | 110 | 127 | 107 |
| 37 | 2C1-17 | 1.5 | 102 | 305 | 356 | 457 | 102 | 102 | 1 | 1.9 | 422 | 19.9 | 0.3 | 460 | 0.2 | 124 | 123 | 133 | 109 |
| 38 | 2C3-03 | 1.5 | 102 | 305 | 356 | 457 | 102 | 102 | 1 | 1.9 | 422 | 19.2 | 0.3 | 460 | 0.4 | 104 | 119 | 129 | 108 |
| 39 | 2C3-27 | 1.5 | 102 | 305 | 356 | 457 | 102 | 102 | 1 | 1.9 | 422 | 19.3 | 0.3 | 460 | 0.4 | 115 | 119 | 130 | 108 |
| 40 | 2C4-18 | 1.5 | 102 | 305 | 356 | 457 | 102 | 102 | 1 | 1.9 | 422 | 20.4 | 0.3 | 460 | 0.7 | 125 | 126 | 135 | 111 |
| 41 | 2C6-19 | 1.5 | 102 | 305 | 356 | 457 | 102 | 102 | 1 | 1.9 | 422 | 20.8 | 0.3 | 460 | 0.9 | 124 | 128 | 137 | 112 |
| 42 | 3C1-20 | 1.5 | 102 | 305 | 356 | 457 | 102 | 102 | 1 | 1.9 | 422 | 21 | 0.6 | 460 | 0.2 | 142 | 129 | 139 | 126 |
| 43 | 3C4-22 | 1.5 | 102 | 305 | 356 | 457 | 102 | 102 | 1 | 1.9 | 422 | 18.3 | 0.6 | 460 | 0.7 | 128 | 114 | 125 | 122 |
| 44 | 3C6-23 | 1.5 | 102 | 305 | 356 | 457 | 102 | 102 | 1 | 1.9 | 422 | 19 | 0.6 | 460 | 0.9 | 137 | 118 | 129 | 121 |
| 45 | [11] | L6 | 1 | 200 | 1000 | 1050 | 1000 | 200 | 200 | 1 | 0.4 | 1016 | 31.2 | 0.3 | 389 | 0 | 665 | 522 | 816 | 693 |
| 46 | L7 | 1 | 400 | 2000 | 2100 | 2000 | 400 | 400 | 1 | 0.4 | 1016 | 30.5 | 0.3 | 375 | 0 | 2584 | 1748 | 3033 | 2558 |
| 47 | [13] | B-3 | 0.5 | 240 | 400 | 475 | 200 | 100 | 100 | 1 | 2.0 | 376 | 36.2 | 0.4 | 376 | 0 | 768 | 551 | 864 | 760 |
| 48 | B-4 | 0.5 | 240 | 400 | 475 | 200 | 100 | 100 | 1 | 2.0 | 376 | 31.3 | 0.8 | 376 | 0 | 976 | 498 | 802 | 697 |
| 49 | B-7 | 1 | 240 | 400 | 475 | 400 | 100 | 100 | 1 | 2.0 | 376 | 31.3 | 0.4 | 376 | 0 | 591 | 345 | 559 | 480 |
| 50 | B-17 | 1.5 | 600 | 1000 | 1105 | 1500 | 250 | 250 | 1 | 2.0 | 398 | 28.7 | 0.4 | 398 | 0 | 2607 | 1046 | 2258 | 2209 |
| 51 | B-18 | 1.5 | 840 | 1400 | 1505 | 2100 | 350 | 350 | 1 | 2.0 | 398 | 23.5 | 0.4 | 398 | 0 | 4198 | 1622 | 3669 | 4076 |
| 52 | [14] | DB35bw | 1.1 | 80 | 313 | 350 | 344 | 53 | 53 | 1 | 1.2 | 455 | 25.9 | 0.4 | 426 | 0 | 100 | 113 | 101 | 98 |
| 53 | 1DB50bw | 1.1 | 115 | 454 | 500 | 499 | 75 | 75 | 1 | 1.3 | 520 | 27.4 | 0.4 | 426 | 0 | 187 | 173 | 203 | 203 |
| 54 | 1DB70bw | 1.1 | 160 | 642 | 700 | 706 | 105 | 105 | 1 | 1.2 | 522 | 28.3 | 0.4 | 426 | 0 | 427 | 276 | 388 | 399 |
| 55 | 1DB100bw | 1.1 | 230 | 904 | 1000 | 994 | 150 | 150 | 1 | 1.2 | 555 | 28.7 | 0.4 | 426 | 0 | 775 | 451 | 754 | 760 |
| 56 | [15] | MS1-3 | 1.2 | 300 | 506 | 607 | 600 | 200 | 200 | 1 | 2.3 | 880 | 44 | 0.3 | 420 | 0.4 | 1374 | 734 | 1316 | 1126 |
| 57 | MS2-3 | 1.8 | 300 | 506 | 607 | 900 | 200 | 200 | 1 | 2.3 | 880 | 43 | 0.3 | 420 | 0.4 | 1028 | 593 | 887 | 767 |
| 58 | [16] | D6.A4.G40#4S | 1.4 | 406 | 1778 | 1829 | 2438 | 203 | 610 | 1 | 0.6 | 470 | 26.2 | 0.3 | 348 | 0 | 1809 | 752 | 1305 | 1739 |
| 59 | D4.A2.G40#4S | 2.1 | 406 | 1168 | 1219 | 2438 | 203 | 610 | 1 | 0.4 | 469 | 25.2 | 0.3 | 349 | 0 | 922 | 418 | 960 | 931 |

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