USE OF HIGH STRENGTH CONCRETE GRADES FOR BUILDINGS & TOWERS

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Abstract – *In recent years, the developed countries have emerged as centers for new high-rise buildings. Residential plots are costly and expensive in big cities. To accommodate the huge population of cities, high-rise buildings are best solution as a product of present need. A high-rise building is any structure, where the height can have a significant impact on evacuation. In this paper, a case study has made considering the site issues for construction of a high rise-building using high strength grade of concrete.*

Key Words: Grade of Concrete, High Strength Concrete Grades, Workability, Slump, NCR (Non-Conformance Report; means issuing a memo or notice to Contractor for deviating the work from Project Specifications / Design Drawings)

1. INTRODUCTION:

The continuing economic prosperity and population increase in urban areas point towards a future with increased activity in high rise construction of residential and official buildings. However, construction of high-rise buildings can be economically attractive only if Structural Engineer can have comprehensive understanding of structural behaviours of various systems on one hand and the practical sense of construction problems on the other hand.

Since 1990's, an increasing number of high-rise buildings have been designed around the world and the tower building industry is still progressing. It has been observed that now-a-days, Structural Designers are using High Strength Grade of Concrete to design High-Rise Buildings and Towers.

1.1 Grade of Concrete & their Classifications:

Grade of concrete is defined as the *characteristic compressive strength of concrete after 28 days cube testing*. Concrete Grade may denote as C-40 or M-40 where C or M indicates Cube Test and 40 is strength of concrete (after 28 days cube testing) as 40 N/sq.mm OR (40 MPa).

a) Normal Grade of Concrete:
   - C-10 to C-20 or (M10 to M20) – Cube Strength = 10 to 20 N/sq.mm (MPa)

b) Standard Grade of Concrete:
   - C-25 to C-50 or (M25 to M50) – Cube Strength = 25 to 50 N/sq.mm (MPa)

c) High Strength Grade of Concrete:
   - C-55 to C-90 or (M55 to M90) – Cube Strength = 55 to 90 N/sq.mm (MPa)

1.2 Grade of Concrete used for Buildings / Towers:

Normally, the following Grades of Concrete are using to design the High-Rise Buildings for different structural elements:

Standard Grade of Concrete for Horizontal members:
- Slabs & Beams: C30 to C45 (30 to 45 N/sq.mm) MPa

Standard Grade of Concrete for Foundation:
- Pile Caps, Footings and Raft Foundation: C40 to C50 (40 to 50 N/sq.mm) MPa.

High Strength Concrete Grade for Vertical members:
- Columns and Core Walls / Shear Walls: C55 to C90 (55 to 90 N/sq.mm) MPa.

2. CONSTRUCTION OF HIGH-RISE BUILDINGS:

Building / Tower	Year	Floors	Height (mtrs)
The 42 Tower, Kolkata, India	2019	63	268.00
PETRONAS Twin Towers, Kualalumpur - Malaysia	1998	82	451.90
TAIPEI 101 Tower - China	2004	101	508.00
WORLD TRADE CENTER, New York – U.S.A.	2014	110	541.30
CLOCK TOWER, Makkah Mukarramah – K. S. A.	2012	120	601.00
SHANGAI Tower - China	2015	128	632.00
BURJ KHALIFA Tower, Dubai – U. A. E.	2010	163	827.80
JEDDAH Tower – K. S. A. (under construction)	-----	168	1000.00

3. NEED OF HIGH STRENGTH GRADE OF CONCRETE:

1) To resist extremely high compressive load in core / shear walls and columns.

2) To optimize the thickness of core / shear wall and to minimize the size of columns, especially in lower floors.

3) Critical check for tall buildings - it's acceleration at the top-most floor and lateral sway.

4) Higher Young's modulus of concrete (E) corresponds to higher Stiffness or Rigidity.

5) High Strength Concrete Grades gives Higher Cube/Cylindrical strength, which provides to Higher Young's Modulus (E) value.

4. Dis Advantages of High Strength Concrete Grade:

1) It is costly and hence un-economical.

2) High quality control is required.

3) Experienced technical staff is required.

4) Good material selection is required during mix design to meet high-performance standards consistently.

5. MAIN DIFFERENCE BETWEEN NORMAL / STANDARD & HIGH STRENGTH CONCRETE GRADE:

Particulars	Normal / Standard Conc. Grade	High Strength Conc. Grade
Compressive Strength Testing of Cube / Cylinder	28 days	56 or 90 days
Workability check	Slump Test	Flow Test
Supplementary materials	GGBFS, Fly ash	Micro-silica or Silica Fume along with Fly ash
Water Cement Ratio	More than 0.45	0.27 to 0.45
Admixtures	Not Required	High Range Water Reducing Admixture (HRWRA)

6. COLUMN DESIGN EXAMPLE WITH DIFFERENT GRADES OF CONCRETE:

Let us Design a Short Column using following assumed data:

- Size of Column : 800 x 800mm to 600 x 600mm
- Grade of Concrete: C-40 to C-80 MPa
- Steel reinf: 16 Nos. of 25mm dia.
- **Load Carrying Capacity**:

$$P = 0.45(fcu*Ac) + 0.87(fy*Asc)$$

where,

P - Load Carrying Capacity (kN)
fcu – Grade of Concrete – MPa
Ac – Gross Area of Column Concrete
fy – Yield strength of steel reinf.
fy = 460 MPa
Asc – Area of Steel Reinf - mm^2

6.1 Column Dimensions varies with Conc. Grades:

Conc. Grade (fcu)	Column Sizes (mm)	Steel Reinforcement	Load Carrying Capacity (kN)
40 MPa	800 x 800	16 Nos. of 25mm dia.	14650 kN
45 MPa	775 x 775	16 Nos. of 25mm dia.	15300 kN
50 MPa	750 x 750	16 Nos. of 25mm dia.	15800 kN
55 MPa	725 x 725	16 Nos. of 25mm dia.	16150 kN
60 MPa	700 x 700	16 Nos. of 25mm dia.	16370 kN
70 MPa	650 x 650	16 Nos. of 25mm dia.	16450 kN
80 MPa	600 x 600	16 Nos. of 25mm dia.	16100 kN

Note: - The Column size (800 x 800mm) with C-40 Grade of Concrete may change to (600 x 600mm) using High Strength Grade of Concrete as C-80.

7. HIGH RISE BUILDING CONSTRUCTION & CONTRACTOR'S MISTAKE:

- A residential high-rise building of 36 storied has constructed during 2008.
- The Contractor has made a mistake in pouring of concrete for Ground Floor Columns & Core Wall.
- As per Design Drawings, the Concrete Grade for Slab / Beams was C-45 and Columns / Wall was C-55.
- By mistake, Contractor has poured the concrete to Core Wall & few Columns using C-45 instead of C-55 Grade of Concrete.

8. CONSULTANT ROLE TO RESOLVE THE CONTRACTOR'S MISTAKE:

- ✓ Issued an NCR (Non-Conformance Report) to the Contractor for deviating the Project Specifications and Design Drawings.
- ✓ Sent the report of Contractor's mistake with NCR copy to Design Consultant's Office for re-verification of design and technical solution.
- ✓ Structural Designer has informed to site team for stopping the work till receiving of 28 days cube test results.
- ✓ Hence stopped the work for core wall and few columns casted with wall.

9. STRUCTURAL DESIGNER'S RESPONSE:

a) Received 28 days Cube Test Results with an average value of compressive strength as 53 MPa (53 N/sq.mm) by an Independent Laboratory.

b) Structural Designer has accepted the Cube Test Results as 53 MPa (53 N/sq.mm). But instructed to Contractor for submitting the Cube Test Results after 56 days also.

c) Structural Designer explained that, during design stage, we assumed as C-50 for designing of vertical elements (Columns, Shear / Core Walls) and C-40 for designing of horizontal elements (Slabs / Beams); but mentioned in Design Drawings as C-55 for Column / Walls & C-45 for Slab / Beams.

d) Achieving of 53 MPa Cube test results after 28 days are acceptable. It may also increase after 56 days cube test results.

e) We instructed to Contractor to proceed the construction work of Core Wall and columns which were stopped (one month before).
Fortunately, by maintaining the good quality in ready-mix plant, during mix design, we obtained C-55 MPa (after 56 days) which was shown in Design Drawings, but required is C-50 MPa only (as per Design).

f) Structural Designer has provided soft copy of Structural Design Calculations (in pdf format) and also the ETABS / SAFE model for Building Design to prove that the Grades of Concrete were assumed as C-50 for Columns / Walls, C-40 for Slabs / Beams.

g) But the Structural Designer has shown on Drawings as C-55 for Columns / Walls (instead of C-50) and C-45 for Slabs / Beams (instead of C-40) as safer side for execution purpose at site.

10. CONCLUSIONS:

- Keeping a margin of 5 MPa for using the Grades of Concrete by the Structural Designer is an advantageous to site execution team.
- Issued instruction to Contractor for mentioning the Grade of Concrete on each structural shop drawing and also on related structural RFI's (Request for Inspection forms) based on drawings & Project Specifications.
- Issued instructions to Contractor for maintaining the record of concrete receiving to site with all details.
- Closed NCR by instructing, not to repeat these types of major mistakes.
- If Grade of Concrete for Columns / Walls were C-70 or C-80, then the Contractor will be in trouble to demolish the wrongly casted structural elements
- Municipal authorities may block the Contractor's license or may not renew the license in future, if the Contractor will not follow the Project Specs & Design Drawings.

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REFERENCES

No references – only Case study based on site experience.

BIOGRAPHIES

Passed Bachelor's Degree in Civil Engineering (1989) and Master's Degree in Structural Engineering (1996) from Khaja Banda Nawaz College of Engineering, Gulbarga University, (Kalaburagi) – Karnataka State, India.

Working in GCC from last 23 years for site supervision & structural designing works.

Passed Dubai Municipality Test for designing of Buildings up to G+12 structures.

Presently working as a Project Engineer (Civil) at ZFP Consultants, Riyadh from December 2011.

Previously worked with Lootah, HADI, ATKINS Consultants in Dubai for 13+ years and PARSONS in Yanbu KSA for 2 years.