CEL 232 CONCRETE MATERIALS & DESIGN

http://web.iitd.ac.in/~sbhalla/cel232.htm

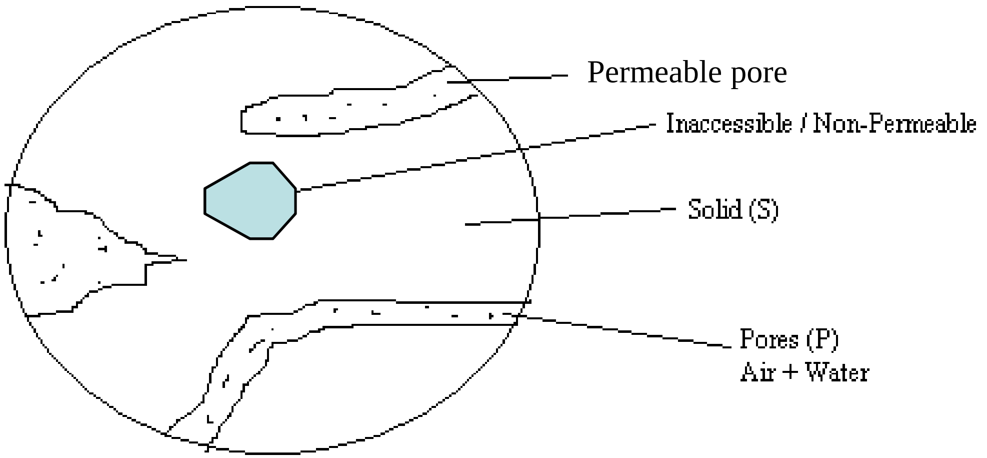
CONSTITUENTS OF CONCRETE

- CEMENT
- FINE AGGREGATE
- COARSE AGGREGATE
- WATER

THIS COURSE LAYS SPECIAL EMPHASIS ON TESTING OF THESE MATERIALS

CEL 232 CONCRETE MATERIALS & DESIGN

SPECIFIC GRAVITY OF AGGREGATE



Solids

Pores

$$V = V_S + V_P$$

$$V = V_S + (V_{PP} + V_{NP})$$

Permeable

Non-permeable

Absolute specific gravity = $\dfrac{M_S}{V_S \rho_W}$

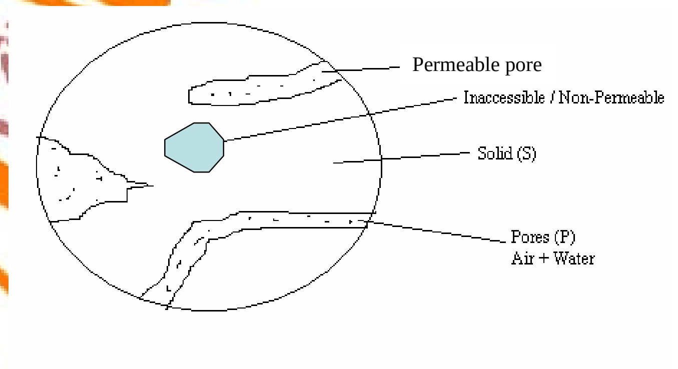
M_S = Mass of solids
(equal to the mass of perfectly dried aggregate, obtained after prolonged heating)

V_{PP} = Vol. of permeable pores
(equal to vol. of water absorbed if soaked for a long time)

V_{NP} = Vol. of non-permeable pores
(Cannot be determined)

DEFINITIONS OF SPECIFIC GRAVITY

Average specific gravity $S_{av} = \dfrac{M_S}{(V_S + V_{PP} + V_{NP})\rho_W}$



Apparent specific gravity $S_{app} = \dfrac{M_S}{(V_S + V_{NP})\rho_W}$

Gross apparent specific gravity $S_{SSD} = \dfrac{M_S + V_{PP}\rho_W}{(V_S + V_{PP} + V_{NP})\rho_W}$

Weight of aggregate in Saturated Surface Dry (SSD) condition

under saturated surface-dry (SSD) condition

Bulk density =

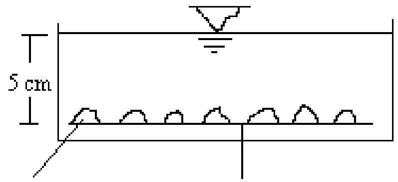
Mass of aggregate required to fill a container of unit volume.

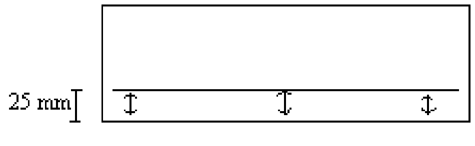
PROCEDURE FOR COARSE AGGREGATE

1. Wash the aggregate thoroughly.
2. Put in wire basket (6.3mm) and immerse in distilled water (22°C – 32°C).
3. Let the basket be in water for 24 hours.
4. Weigh basket inside water = A_1
5. Empty aggregate on dry cloth.
6. Weigh empty basket inside water (jolt 25 times) = A_2

Weight of water displaced

$A = A_1 - A_2$ = Weight of aggregate in water, with permeable pores filled up $M_s g - (V_S + V_{NP})\rho_W g$





$$A = M_s g - (V_S + V_{NP})\rho_W g$$

7. After transfer to dry cloth, wipe water, then transfer to another dry cloth (when 1st can't remove any further). When no surface moisture, weigh them = B

$$B = (M_S + V_{PP}\rho_W)g$$

8. Heat the aggregate in oven @ 100-110ºC for 24 hrs. Cool in an airtight container, weigh them = C

$$C = M_S g$$

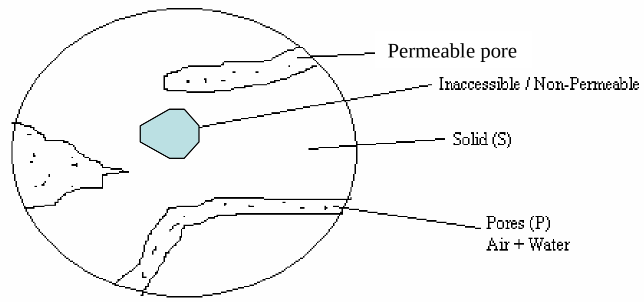
Average specific gravity $S_{av} = \dfrac{M_S}{(V_S + V_{PP} + V_{NP})\rho_W} = \dfrac{C}{(B - A)}$

Apparent specific gravity $S_{app} = \dfrac{M_S}{(V_S + V_{NP})\rho_W} = \dfrac{C}{(C - A)}$

Gross apparent specific gravity (SSD) $S_{SSD} = \dfrac{M_S + V_{PP}\rho_W}{(V_S + V_{PP} + V_{NP})\rho_W} = \dfrac{B}{(B - A)}$

Water absorption $= \dfrac{V_{PP}\rho_w}{M_S} X100 = \dfrac{(B - C)}{C} \times 100$

V_{PP}

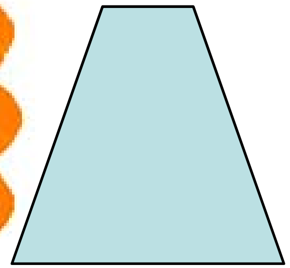


Why Important ?

- ❖This much water absorbed during concrete mix preparation.
- ❖Will not aid in workability and chemical hydration of cement.
- ❖Therefore weight of aggregate corresponding to saturated surface dry condition is used.
- ❖Concrete mix design is done on the basis of S_{SSD}.
- ❖*Aggregate should be in saturated surface dry condition at the time of mixing.*

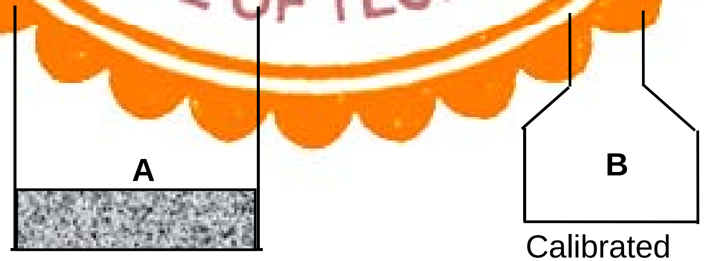
PROCEDURE FOR FINE AGGREGATE

1. Take aggregate preferably partially saturated.
2. Add water in small amount, check if SSD condition is reached, by filling a conical mould. SSD condition is reached at that stage at which the mould "just" stabilizes. Weigh the entire sample
3. Weigh a small sample of fine aggregate in SSD (pores just filled, no extra moisture sticking) = B.



$$B = \left(M_S + V_{PP}\rho_W\right)g$$

4. Keep the sample in a jar. Add water from beaker to the sample such that total vol. = 500 ml . Stir well to remove trapped air, if any.



Calibrated jar

Calibrated beaker

Known vol. added from beaker

$$B = \left(M_S + V_{PP}\rho_W\right)g$$

$$V_{PP} + (V_{NP} + V_S) + V_W = 500$$

$$V_{PP} + V_{NP} + V_S = 500 - V_W = V$$

5. Dry the entire sample (Water + FA Mix) in oven and find $C = M_s g$

   Alternatively, dry the other left portion of the cone, find dry weight and do proportioning to arrive at the dry mass of the sample put in the jar.

Gross apparent specific gravity (SSD) $S_{SSD} = \dfrac{M_S + V_{PP}\rho_W}{(V_S + V_{PP} + V_{NP})\rho_W} = \dfrac{B}{Vg\rho_w}$

Water absorption $= \dfrac{V_{PP}\rho_w}{M_S} X100 = \dfrac{(B-C)}{C} \times 100$

Average specific gravity $S_{av} = \dfrac{M_S}{(V_S + V_{PP} + V_{NP})\rho_W} = \dfrac{C}{Vg\rho_w}$

$$B = \left(M_S + V_{PP}\rho_W\right)g$$

$$C = M_S g$$

$$V_{PP} = \frac{B - C}{\rho_w g}$$

$$V_{PP} + V_{NP} + V_S = 500 - V_W$$

$$V_{NP} + V_S = 500 - V_W - V_{PP}$$

Apparent specific gravity $S_{app} = \dfrac{M_S}{\left(V_S + V_{NP}\right)\rho_W}$

CEL 232 CONCRETE MATERIALS & DESIGN

SIEVE ANALYSIS OF AGGREGATE

Concrete = Cement + FA + CA + Water

CA = Coarse aggregate

FA = Fine aggregate

Particle size distribution is necessary for characterization.

Important if we have to design a mix of given workability or to have least voids.

<u>IS 2386:</u>

Fine Aggregate (FA) : which passes through 4.75 mm sieve i.e <= 4.75 mm

Coarse Aggregate (CA) : size > 4.75mm

SIEVES:

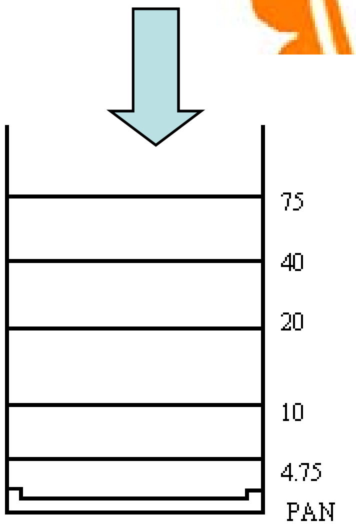
CA (perforated plate type, square holes): 75, 40, 20, 10, 4.75 (in mm)

FA (wire mesh) : 4.75, 2.36, 1.18, 0.6, 0.3, 0.15, 0.075 (in mm)

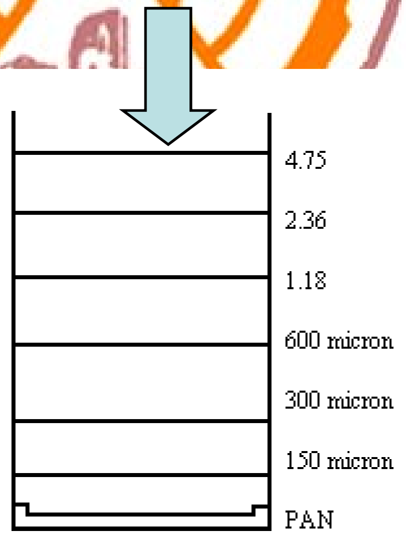
Not suitable for very fine powders (eg. cement). Tend to clog together and stick to the wires

PROCEDURE:

CA
10Kg sample



FA
1 Kg sample



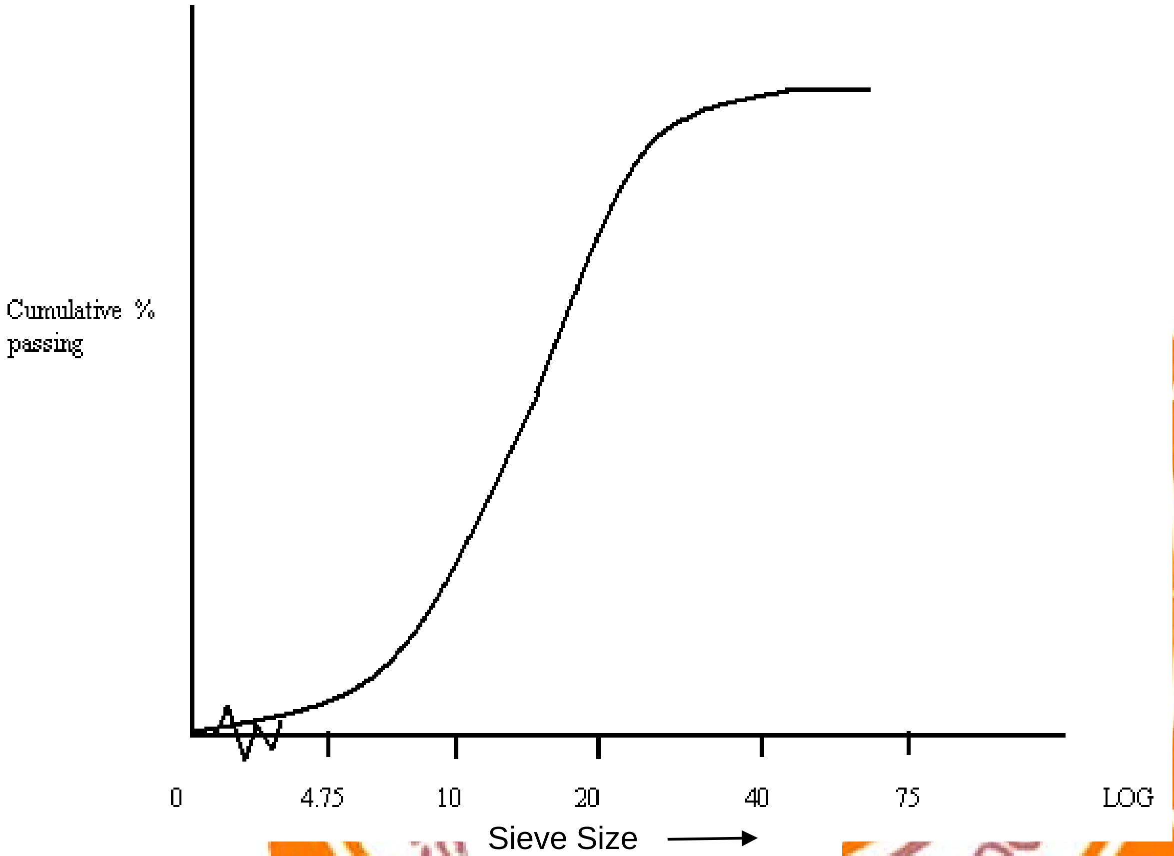
SHAKE FOR 20 MINUTES

Wt. of empty tray = W_1

Wt . of tray + aggregate = W_2

Therefore weight retained = R= W_2- W_1

S.No.	Sieve size (mm)	W_1 (g)	W_2 (g)	W= W_2- W_1 (g)	% Retained	Cumulative % retained	Cumulative % wt. passing
1	75					R_1	100 - R_1
2	40					R_2	100 – R_2
3	20					R_3	100 – R_3
4	10					R_4	100 – R_4
5	4.75					R_5	100 - R_5
	PAN						
					$\sum$		



Fineness modulus = $\frac{\sum \text{cumulative \% retained}}{100}$

~ weighted average size of sieve on which materials shall be retained (Starting from least size)

To derive the grading curve for a mixture of two different aggregate

$Ø_1$ = fraction of Aggregate A_1 $Ø_2$ = fraction of Aggregate A_2

Sieve size	% retained R_1 R_2	% retained for mixture = $Ø_1 R_1 + Ø_2 R_2$	Cumulative % retained	Cumulative % passing
75				
40				
20				
10				

CEL 232 CONCRETE MATERIALS & DESIGN

TESTS OF CEMENT

Normal Consistency (NC)

Water demand of cement (optimum quantity of water just sufficient to produce desired results)

Initial setting time (IST)

Time after which cement based mortar is unfit to be used
(should be > 30min).

Final setting time(FST)

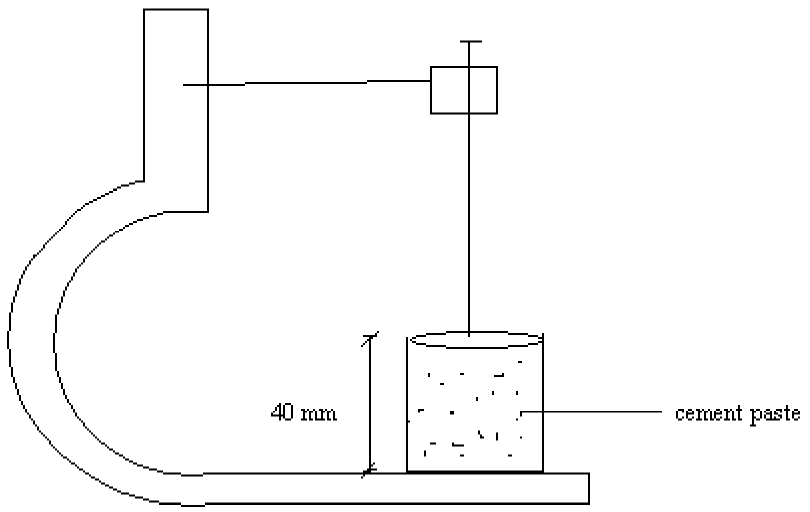
Time after which cement attains reasonable amount of setting, formwork can be removed
(should be < 10 h) .

QUANTITATIVE DEFINITIONS

NC = That water content at which Vicat's Plunger penetrates a depth of 33-35mm. (generally in the range of 30-35% for most cements).

IST = Time after which Vicat's needle does not penetrate beyond 35mm.

FST = Time after which no mark by standard annular ring of specified weight.



VICAT'S APPARATUS

NORMAL CONSISTENCY- PROCEDURE

1. Assume certain water content = ***w (%)***

2. Determine the weight of water for a cement weight w_c = 400g

   $$w_w = (w/100) x w_c$$

3. Mix the two for 3 to 5 minutes using fingers.

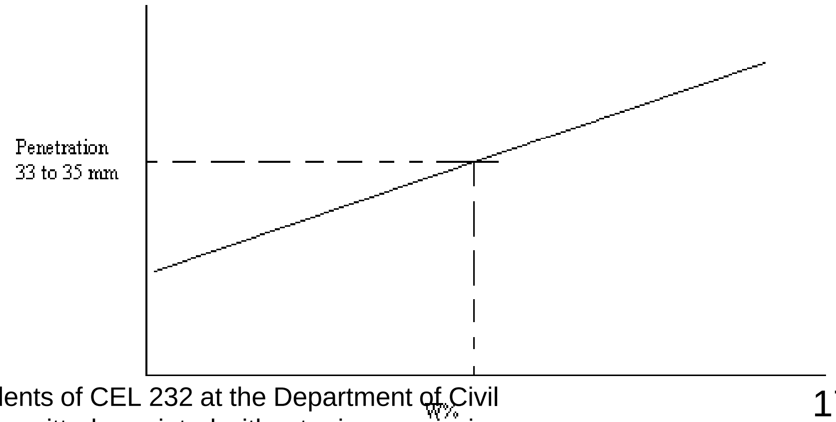
4. Transfer into mould, touch the plunger to top surface and release it, note the penetration.

5. Repeat until successful.

6. NC = Water content @ which penetration = 33 to 35 mm

PRECAUTIONS:

- Plunger should be released without any pressure / jerk.
- Plunger should be cleaned before each testing.
- Temperature 25 – 30 ^{o}C



INITIAL SETTING TIME: PROCEDURE

1. Determine the weight of water for w_c = 400g

$$w_w = (0.85 w_{NC} / 100) \times w_c$$

w_{NC} = water content corresponding to normal consistency.

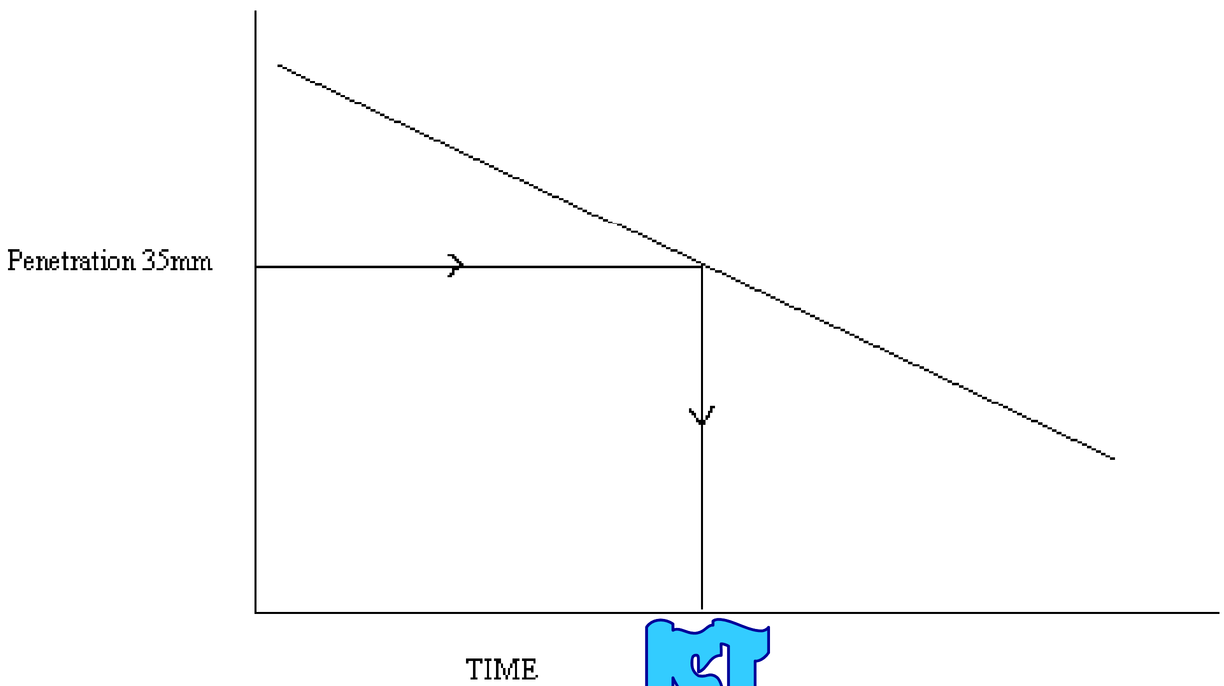
2. Start stop watch at instant water is added.

3. Mix 3 to 5 minutes with fingers.

4. Fill Vicat's mould smooth top.

5. Allow needle to penetrate. Note penetration and time.

6. Repeat untill a penetration of 35 ±0.5 mm achieved. IST = that time.


Penetration 35mm
TIME

FINAL SETTING TIME: PROCEDURE

1. Determine the weight of water for w_c = 400g

$$w_w = (0.85 w_{NC} / 100) \times w_c$$

w_{NC} = water content corresponding to normal consistency.

2. Start stop watch at instant water is added.
3. Mix 3 to 5 minutes with fingers.
4. Fill Vicat's mould smooth top.
5. Apply the annular ring on top. Needle should be able to make impression whereas the ring should not. FST = that time.

SPECIFIC GRAVITY OF CEMENT

Specific gravity = $\dfrac{M_S}{V_S \rho_W}$

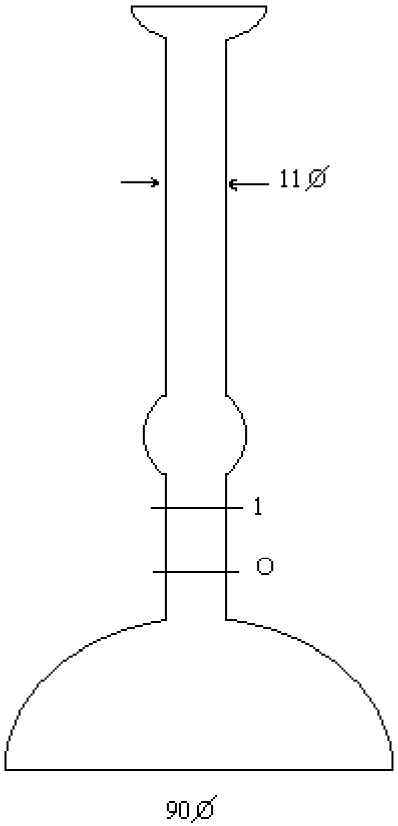
Practical relevance– For quality check.

Specific gravity **= 3.15 for ordinary portland cement.**

If not, it suggests-Adulteration (ground sand, fly ash etc.) or partly hardened cement (prolonged storage)

V_s can be found by immersing cement in a liquid and determining the volume of the liquid displaced.

1. **Liquid should not have chemical reaction with cement.**
2. **No adsorption.**
3. **Should not use polar liquid.**
4. **No agglomerated particle in cement sample (internal voids).**

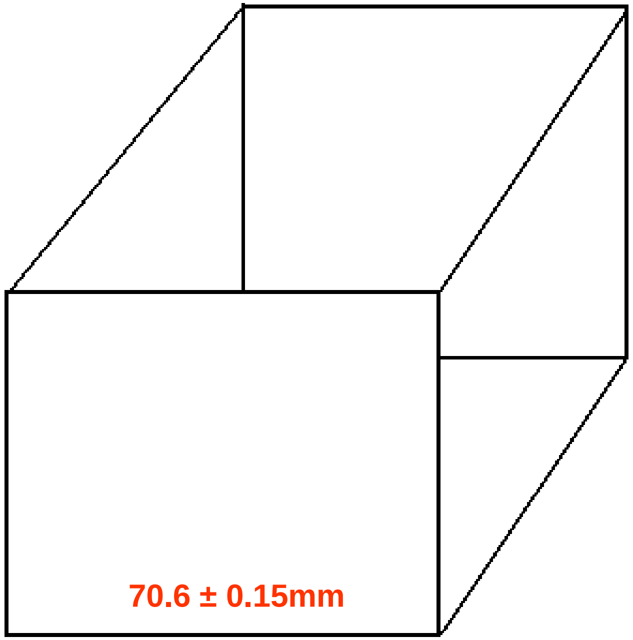


Test 4 sample. 4 groups

1. Fill flask between 0 & 1.
2. Immerse in water bath, take reading.
3. Add 64 g cement. Place stopper (use vibrator).
4. Immerse in water bath & record final reading.
5. V_s = final reading – initial reading.

COMPRESSIVE STRENGTH OF CEMENT

- **Hardened cement paste shrinks and cracks. Therefore, large specimens cannot be made with it.**
- **Therefore, pure cement is not tested. Cement- sand mortar (with standard sand) specimens are tested.**
- **Deterioration of strength due to storage can be tested by this experiment.**
- **Adulteration of cement can also be tested.**



Each Face Area = 50 cm2

PROCEDURE

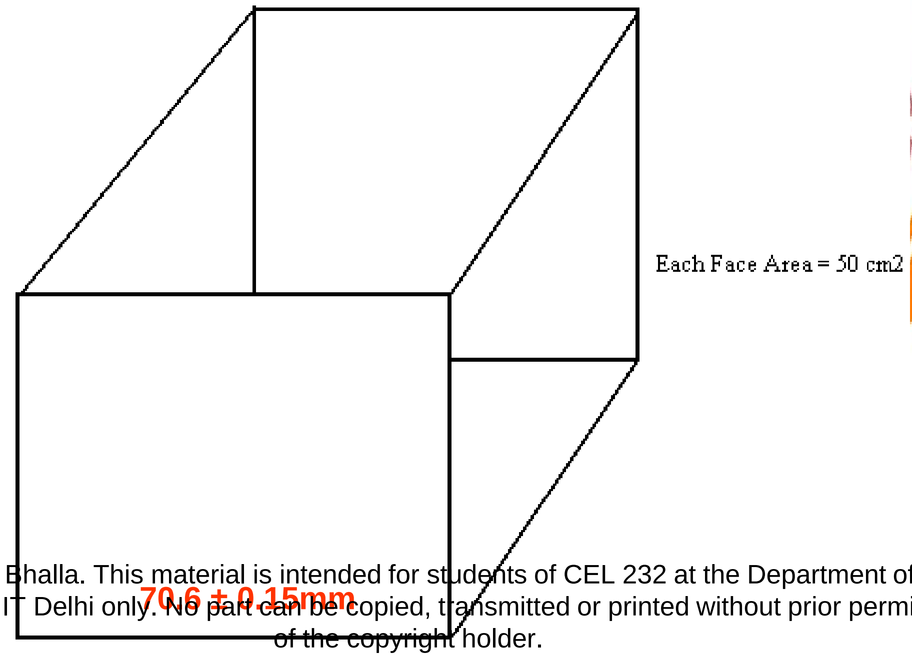
1. **Desired temperature 25 – 29^{o}C**
2. **Cement (200g) : sand(600g)** **TOTAL = 800g Mix uniformly**

   Add Water = $\left(\frac{W_{NC}}{4}+3.5\right)\%$ of 800g

3. **Prepare the moulds– apply petroleum jelly and oil.**
4. **Mix the constituents. Mixing time should be < 4 min (else reject the sample)**
5. **Fill moulds and vibrate.**
   - **Prod by rod 20 times in 8s to eliminated air.**
   - **Add again and repeat above step.**
   - **Vibrate for 2 minute @ 12000 ± 400 vibrs. per min.**
   - **Smoothen the top**
6. **Keep moulds at 25 – 29^{o}C and 90% relative humidity for 24 hours.**
7. **Remove moulds and submerge in fresh water 25 – 29^{o}C until immediately before testing.**
8. **Test 4 cubes each for compressive strength after 7 days and 28 days. Loading rate = 350kg/cm^{2}/min**

COMPRESSIVE STRENGTH OF CEMENT

- **Test 4 cubes each for compressive strength after 7 days and 28 days.**
- **Cubes should be tested immediately after taking out of curing tank (should not be allowed to dry)**
- **No packing should be placed.**
- **Loading rate = 350kg/cm2/min.**
- **Compare the strength achieved with desired values as per IS 269/8112/12269 depending on grade of cement.**



CEL 232 CONCRETE MATERIALS & DESIGN

CONCRETE MIX DESIGN

REFERENCES:

SP 23 (1982) (Handbook on Concrete mix)
IS 456: 2000
IS 383: 1970

GIVEN:

Cement grade 43 $\rho_c = 3150$ kg/m^3

Aggregate : **CA = 10 mm MSA crushed / angular** $\rho_{CA} = 2624$ kg/m^3
FA = zone III sand $\rho_{FA} = 2589$ kg/m3

Workability = medium

Exposure = Moderate.

Purpose = For reinforced concrete.

Sieve	% Passing
10	100
4.75	93
2.36	86.5
1.18	70.5
0.6	58.5
0.3	20.0
0.15	7.5
Pan	0.5
Zone III	

SUMMARY OF DESIGN STEPS

1. **Decide concrete grade and workability.**
2. **Water cement ratio.**
3. **Air content.**
4. **Water content and composition of aggregate (proportion of CA and FA)**
5. **Adjustments in water content (WC) and composition of aggregate.**
6. **Cement content.**
7. **Quantity of aggregate.**

1. Decide concrete grade and workability

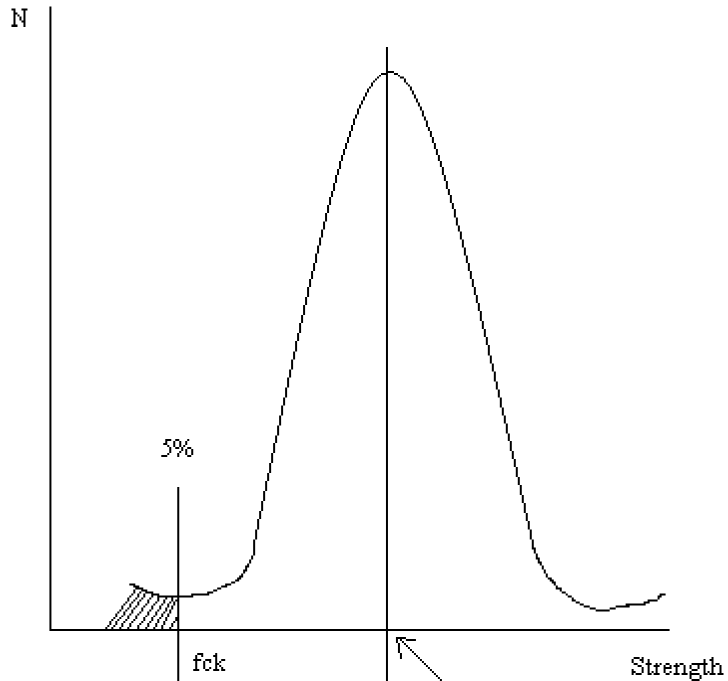
Table 5, page 20, IS: 456 (2000)
Grade of concrete = M25
Target mean strength.

$$f_t = f_{CK} + KS$$

= 31.6 N / mm

K = 1.65, S = 4 (table 8, IS:456)

Medium workability => CF = 0.9
(Table 22 SP 23)



SUMMARY OF DESIGN STEPS

1. **Decide concrete grade and workability.**
2. **Water cement ratio.**
3. **Air content.**
4. **Water content and composition of aggregate (proportion of CA and FA)**
5. **Adjustments in WC and composition of aggregate.**
6. **Cement content.**
7. **Quantity of aggregate.**

2. Water cement ratio

Fig. 47 SP 23

WCR = 0.45

< max. WCR of table 5 (IS 456)

or Fig. 1.12, page 29 of text book (TB)

SUMMARY OF DESIGN STEPS

1. Decide concrete grade and workability.
2. Water cement ratio.
3. Air content.
4. Water content and composition of aggregate (proportion of CA and FA)
5. Adjustments in WC and composition of aggregate.
6. Cement content.
7. Quantity of aggregate.

3. Air Content

Table 41 SP23, air content = 3%

$$\frac{V_{Air}}{V_{total}} = 0.03$$

$$For \quad V_{total} = 1m^3, \; V_{Air} = 0.03m^3$$

SUMMARY OF DESIGN STEPS

1. Decide concrete grade and workability.
2. Water cement ratio.
3. Air content.
4. Water content and composition of aggregate (proportion of CA and FA)
5. Adjustments in WC and composition of aggregate.
6. Cement content.
7. Quantity of aggregate.

4. Water content and composition of aggregate

Table 42 SP 23 or Table 1.15, page 36 of TB)

WC (kg/m^3)

$$f = \left(\frac{V_{FA}}{V_{FA} + V_{CA}} \right)$$

208

40% (0.4)

FOR W/C = 0.6, workability=0.8 CF,zone II FA Angular CA

SUMMARY OF DESIGN STEPS

1.Decide concrete grade and workability.

2.Water cement ratio.

3.Air content.

4.Water content and composition of aggregate (proportion of CA and FA)

5.Adjustments in WC and composition of aggregate.

6.Cement content.

7.Quantity of aggregate.

5. Adjustment in Water content and composition of aggregate

FOR W/C = 0.6, workability=0.8 CF,zone II FA Angular CA

Table 44, SP 23 or Table 1.15, page 37 of TB

	WC (kg/m^3)	$f = \left(\dfrac{V_{FC}}{V_{FA} + V_{CA}} \right)$
	208	40% (=0.4)
1. Sand type	0	-1.5%
2. CF	6.24 (3%)	0
3. WCR diff.(= -0.15)	0	-3%
4. Round aggregate.	NA	NA
	WC=214.24 kg / m^3	f = 35.5% (=0.355)

SUMMARY OF DESIGN STEPS

1.Decide concrete grade and workability.

2.Water cement ratio.

3.Air content.

4.Water content and composition of aggregate (proportion of CA and FA)

5.Adjustments in WC and composition of aggregate.

6.Cement content.

7.Quantity of aggregate.

6. Cement Content

$$WCR = 0.45 = \frac{M_W}{M_C} \Rightarrow \frac{214.24 kg/m^3}{M_c} \Rightarrow M_c = 476.09\ kg/m^3$$

Check 1:

Should be > Table 5,6 IS 456 (340 kg / m³) **OK**
Should be > Table 23 SP23 : (290kg/m³) **OK**

Check 2:

Should be < 450 kg / m³ (IS 456)

Not satisfied. What to do?

Reduce water content by adding admixture

SUMMARY OF DESIGN STEPS

1. Decide concrete grade and workability.
2. Water cement ratio.
3. Air content.
4. Water content and composition of aggregate (proportion of CA and FA)
5. Adjustments in WC and composition of aggregate.
6. Cement content.
7. Quantity of aggregate.

6. Cement Content

Add admixture CICO

= 0.6% of cement content = 2.8564 kg/m³

Reduce water content by 30 kg/m³ i.e WC = 184.24 kg/m³

$$\frac{M_W}{M_C} = 0.45 = \frac{184.24 kg/m^3}{M_c} \Rightarrow M_c = 409.42 \text{ kg/m}^3$$

Satisfies both Check 1 and Check 2

SUMMARY OF DESIGN STEPS

1. **Decide concrete grade and workability.**
2. **Water cement ratio.**
3. **Air content.**
4. **Water content and composition of aggregate (proportion of CA and FA)**
5. **Adjustments in WC and composition of aggregate.**
6. **Cement content.**
7. **Quantity of aggregate.**

7. Quantity of Aggregate

$$V = V_{Air} + V_W + V_{ad} + V_C + (V_{CA} + V_{FA})$$

$$= V_{Air} + V_W + V_{ad} + V_C + \frac{V_{FA}}{f}$$

$$= V_{Air} + \frac{M_W}{\rho_W} + \frac{M_{ad}}{\rho_{ad}} + \frac{M_C}{\rho_C} + \frac{M_{FA}}{\rho_{FA} f}$$

$$f = \left(\frac{V_{FC}}{V_{FA} + V_{CA}} \right)$$

Solving $M_{FA} = 579.53 kg / m^3$

Similarly, $V = V_{Air} + \frac{M_W}{\rho_W} + \frac{M_{ad}}{\rho_{ad}} + \frac{M_C}{\rho_C} + \frac{V_{CA}}{(1-f)}$

=> $M_{CA} = 1052.91 kg / m^3$

SUMMARY OF DESIGN STEPS

1. Decide concrete grade and workability.
2. Water cement ratio.
3. Air content.
4. Water content and composition of aggregate (proportion of CA and FA)
5. Adjustments in WC and composition of aggregate.
6. Cement content.
7. Quantity of aggregate.

FINAL RESULT

Mass (kg)	Water	Cement	FA	CA
	184.24	409.42	579.53	1052.91
Ratio by mass	0.45 :	1 :	1.415 :	2.571

SUMMARY OF DESIGN STEPS

1.Decide concrete grade and workability.

2.Water cement ratio.

3.Air content.

4.Water content and composition of aggregate (proportion of CA and FA)

5.Adjustments in WC and composition of aggregate.

6.Cement content.

7.Quantity of aggregate.

SITE ADJUSTMENT FOR MOISTURE IN FINE AGGREGTE

Let FREE moisture in FA = 2.5%

Therefore, water already present = $\frac{2.5}{100} \times M_{FA} = 14.49 kg/m^3$

Moisture in sand (table 10: IS 456)

Therefore, Actual water required = 184.24 – 14.49
= 169.75kg/m^3

Actual sand required = 579.53 + 14.49
= 594.02 kg/m^3

Table 10, IS 456

Condition	% water by mass
Very wet sand	7.5
Moderately wet sand	5.0
Moist sand	2.5%
Moist rock / gravel	1.25 – 2.5 %

CEL 232 CONCRETE MATERIALS & DESIGN

WORKABILITY OF FRESH CONCRETE AND CASTING OF SPECIMENS

Workability = Ease with which fresh concrete can be worked upon

EASE OF:

- **Mixing and Placing**
- **Compacting**
- **Mobility**
- **Finishing**

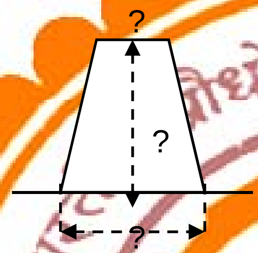
SLUMP TEST

COMPACTION FACTOR TEST

VE BE TIME

SLUMP TEST

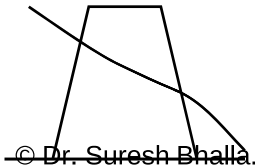
Vertical settlement of a standard frustum of a cone of fresh concrete



PROCEDURE

- 4 layers, tap 25 times with rod, which should penetrate into the layer below.
- Flush surface
- Gradually remove frustum
- Measure settlement

Not preferred for very stiff mixes. Because settlement too small to be measured accurately.



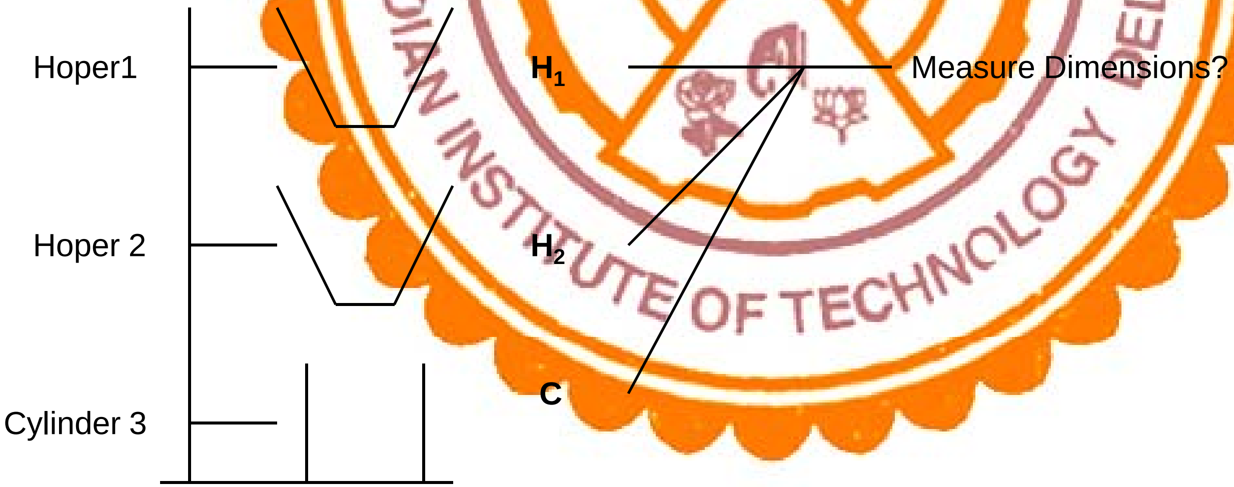
Failure in shear called segregation

COMPACTION FACTOR TEST

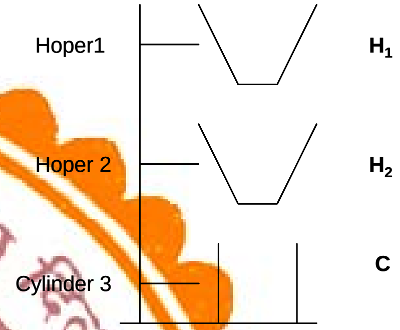
Measure of density to which fresh concrete can be compacted by standard hopper (given standard amount of energy) relative to maximum theoretical density of zero air voids.

Suitable for mixes with moderate workability.

EXPERIMENTAL SET UP



COMPACTION FACTOR TEST



PROCEDURE

- Fill H_1 without any compaction effect.
- Release after 2 minutes (PURPOSE: To compact with standard energy)
- Release H_2 immediately after concrete comes in rest.
- For cylinder C, note following
  - W_1 = Empty weight
  - W_2 = Weight when filled after releasing H_2 and smoothing surface
- Again empty C and refill with same sample in layer of 5 cm thick. Eliminate all air by mechanical vibration.

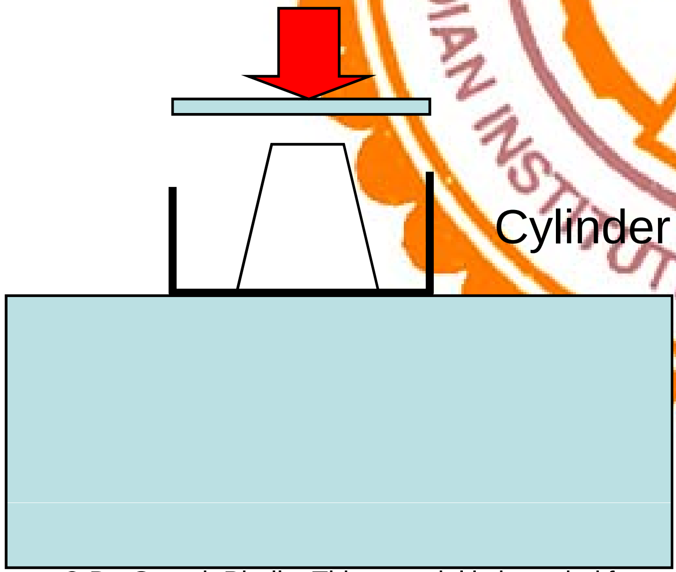
W_3 = Weight of C when filled with fully compacted concrete

$$CF = \frac{W_2 - W_1}{W_3 - W_1}$$

VE BE TIME TEST

PROCEDURE

- Place slump cone in the cylinder of the Ve Be time apparatus, kept on a vibrating table.
- Prepare slump cone as before.
- Remove cone, place transparent disc. Immediately start vibrator and stop watch.



Ve Be Time =

Time required for conical shape to become cylindrical.

Not preferred to highly workable concrete, as very small time cannot be measured accurately.

COMPARISON

Table 22 SP23 / pg 64
Table on page 17 IS456

Workability	Slump (mm)	CF	Ve Be Time (sec)
Very Low			
Low Low reinforcement, mass concreting			
Medium Medium reinforcement 1-2% or pumped concrete			
High very congested reinforcement, Such as beam – column joints (> 3%)			

Unworkable concrete –Can't be compacted / placed properly
=>Poor strength due to large air voids

As water-cement (W/C) ratio increases, strength falls and workability increases.
We have to obtain a trade off

CASTING OF SPECIMENS

10 CUBES (150X150X150MM SIZE) Vol. = ???

10 CYLINDERS (150MM DIA, 300MM HEIGHT) Vol. = ???

4 BEAMS (100X100X500 MM SIZE) Vol. = ???

4 BEAMS (100X100X500 MM SIZE) Vol. = ???

Add 20% extra

Weights of constituents required????
Cement, FA, CA, admixture, water

CASTING OF SPECIMENS (IS 516-1959)

1. **Desired temperature 25 – 29^{o}C**

2. **Prepare the moulds– apply petroleum jelly and oil.**

3. **Prepare the concrete mix.**

3. **Carry out workability test.**

4. **Fill moulds and compact by hand or vibration.**
   - **Each layer should be 5cm thick.**
   - **35 strokes if compacting by hand**
   - **Add again and repeat above step.**
   - **Vibrate for 2 minute @ 12000 ± 400 vibrs. per min.**
   - **Smoothen the top**

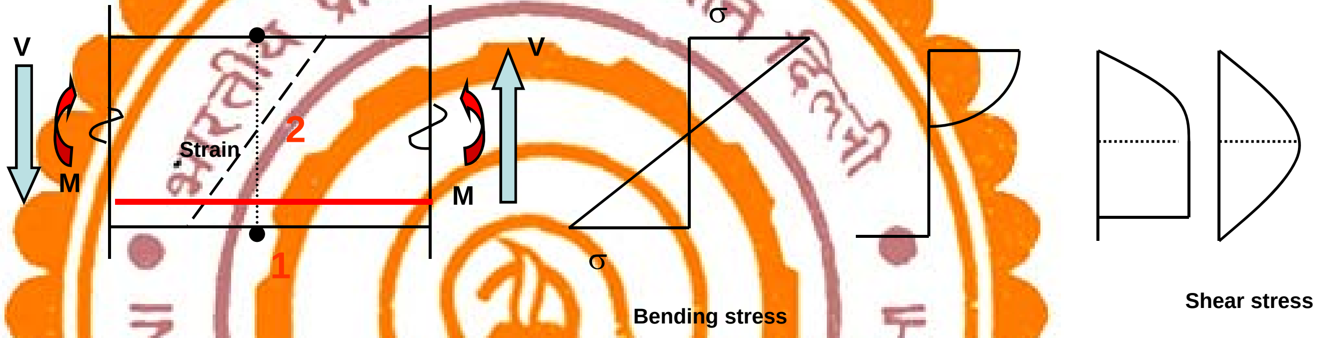
6. **Keep moulds at 25 – 29^{o}C and 90% relative humidity for 24 hours.**

7. **Remove moulds and submerge in fresh water 25 – 29^{o}C until immediately before testing. Water to be renewed after every 7 days.**

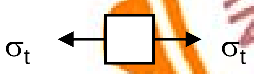
CEL 232 CONCRETE MATERIALS & DESIGN

BEHAVIOUR OF RC BEAMS IN FLEXURE

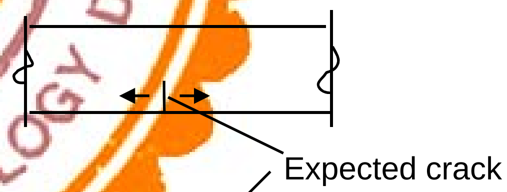
Consider linearly elastic material



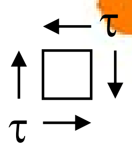
Point 1:
(No shear)



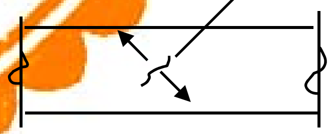
Principal stress = σ_t



Point 2:
(No bending stress)



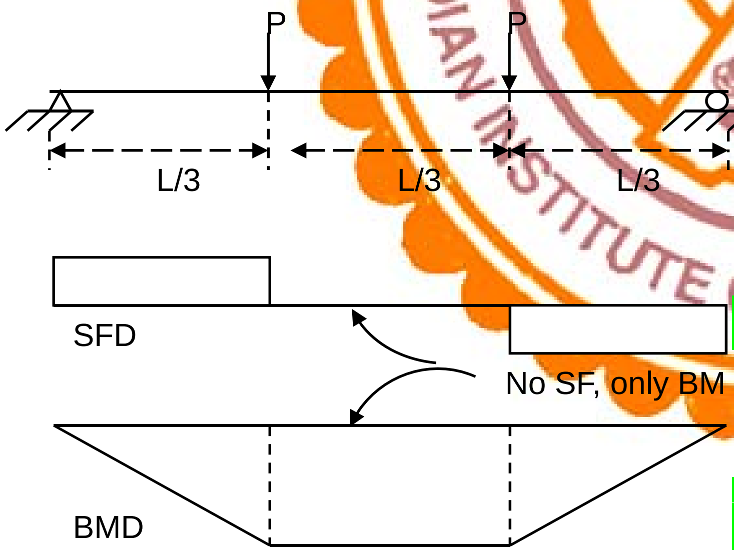
Principal stress = τ



In the case of concrete, stress-strain will be linear for small loads. After cracks develop and at high loads, stress diagram will be non-linear

BEHAVIOUR OF RC BEAMS IN FLEXURE

HOW TO ACHIEVE PURE FLEXURAL BEHAVIOUR ??

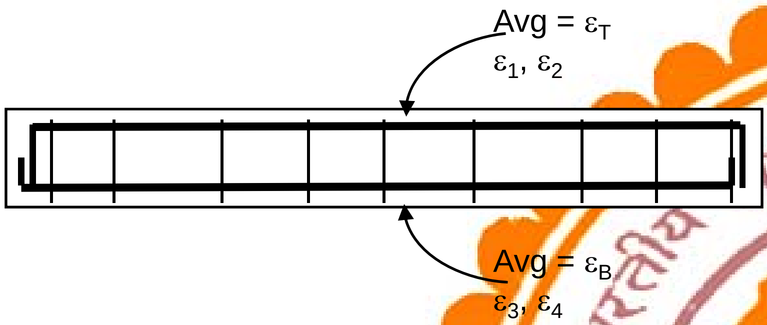


$V = P$

$M = \frac{PL}{3}$

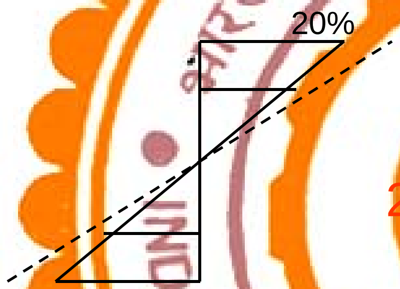
Pure flexural cracks expected in the middle third region.

TEST PROCEDURE



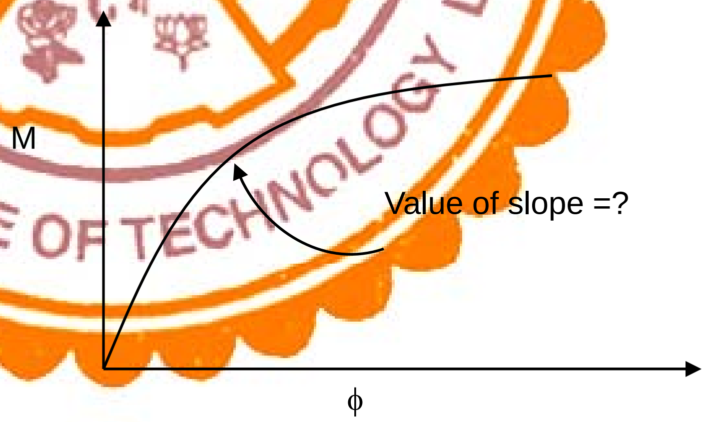
1. Note for the beam: dimensions L, b, D, reinforcement details, location of strain gauges (internal & external).
2. Load the specimen statically and observe and mark the cracks. Note P & ε_1, ε_2, ε_3, ε_4 internal & ε_1, ε_2, ε_3, ε_4, ε_5 external.
3. Plot M Vs Curvature ϕ . M_{ult} =?
4. Calculate M_u using limit state method (Test cubes, get f_{avg} and then f_{ck})
5. Using external strain gauges, check if plane section remains plane?
6. Conclude:
   (a) Ductile or brittle failure
   (b) Comparison between experimental & theoretical M_u, EI

7. Plot variation of strain with depth (based on external strain gauges)- comment whether plane sections remain plane?



20% of Mu, 60 % of Mu, 90 % of Mu

$$\frac{1}{R} = \frac{d^2y}{dx^2} = \phi = \frac{M}{EI}$$



2007 BATCH


THIS LABORATORY IS
UNDER VIDEO/ AUDIO
SURVEILLANCE
WEARING OF SAFETY
SHOE AND HELMET IS
COMPULSORY
88 KN

2009 BATCH

CEL 232 CONCRETE MATERIALS & DESIGN

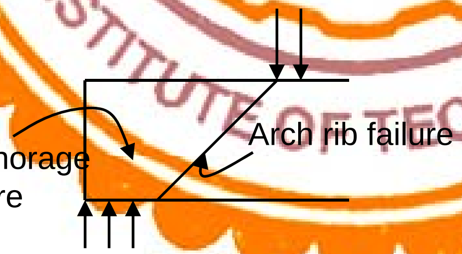
BEHAVIOUR OF RC BEAMS IN SHEAR

Failure types:

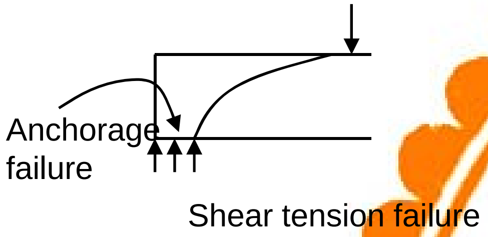
1) Splitting / Compression

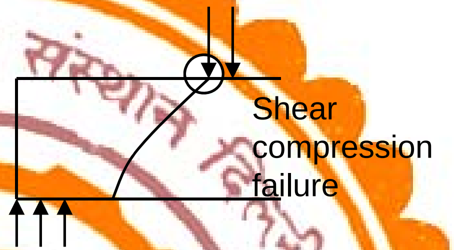
$$a = \frac{Mu}{Vu} =< d$$

a = shear span

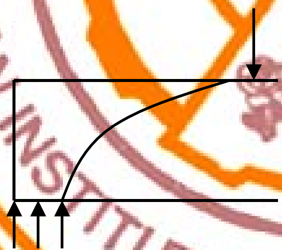


2) Shear compression / tension $\frac{a}{d} =$ Between 1 & 2.5





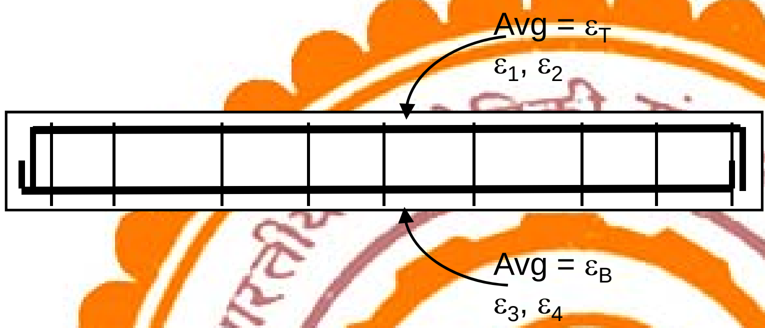
3) Diagonal tension $\frac{a}{d} =$ Between 2.5 & 6.0



- Flexural cracks in beginning
- Diagonal crack

4) Flexural failure $\frac{a}{d} =$ > 6.0

TEST PROCEDURE



1. Note for the beam: dimensions L, b, D, reinforcement details, location of strain gauges (internal & external).

2. Load the specimen statically and observe and mark the cracks. Note P & ε_1, ε_2, ε_3, ε_4 internal

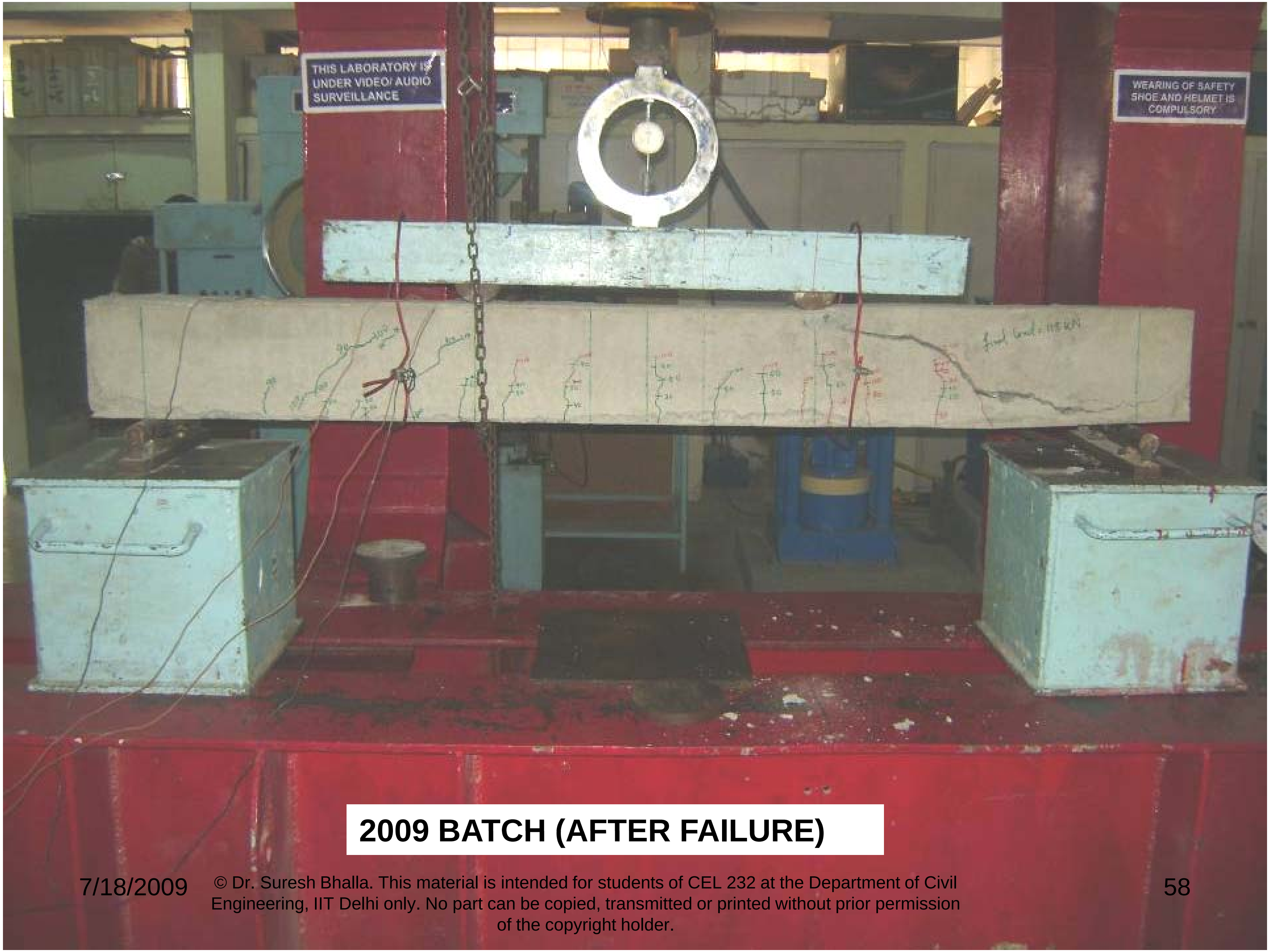
3. Plot M Vs Curvature ϕ . M_{ult} =?

4. Calculate V_u using limit state method (Test cubes, get f_{avg} and then f_{ck})

5. Conclude:
   (a) Ductile or brittle failure
   (b) Comparison between experimental & theoretical V_u


CAP 200 TONS

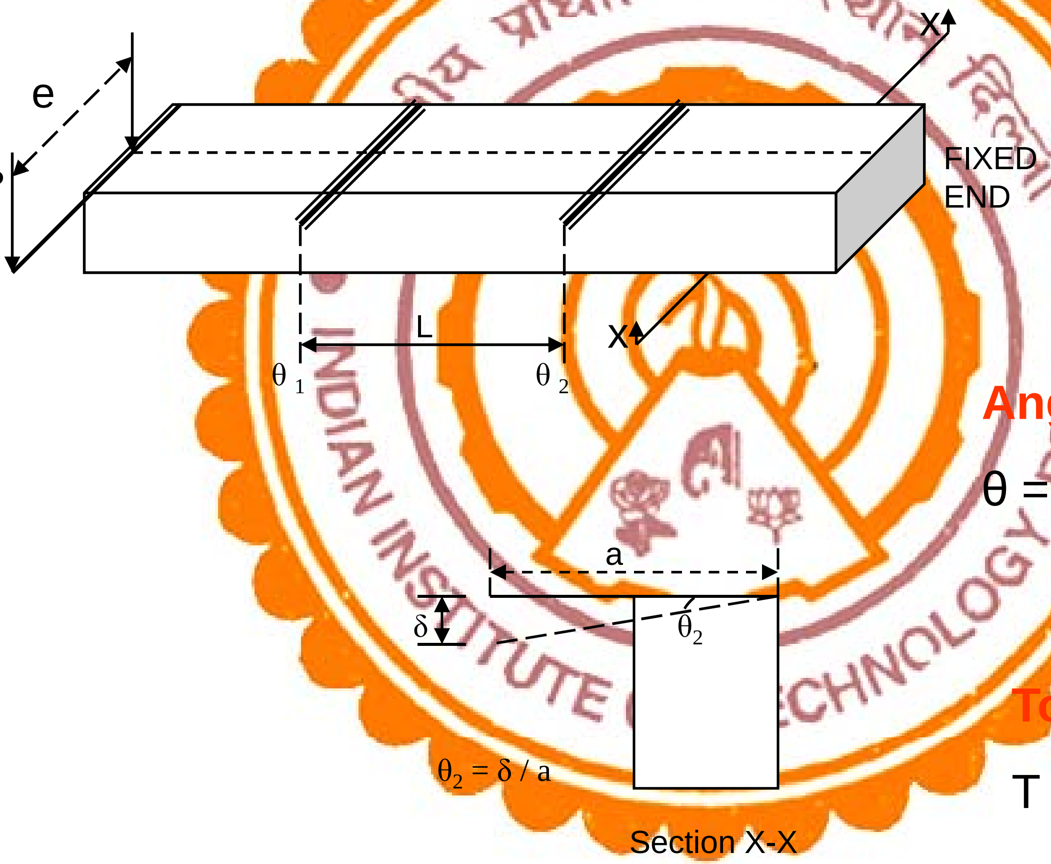
2009 BATCH (JUST BEFORE FAILURE)



2009 BATCH (AFTER FAILURE)

CEL 232 CONCRETE MATERIALS & DESIGN

BEHAVIOUR OF RC BEAMS IN TORSION

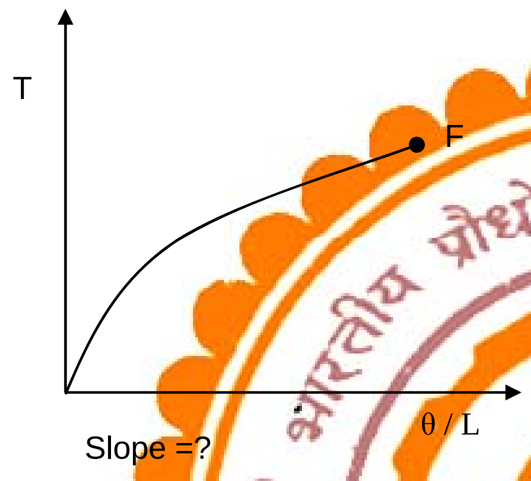


Angle of twist

$\theta = \theta_1 - \theta_2$

Torque

$T = Pe$



;

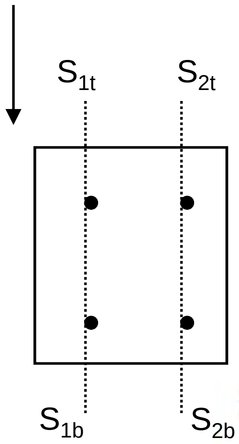
Theoretical GJ =?

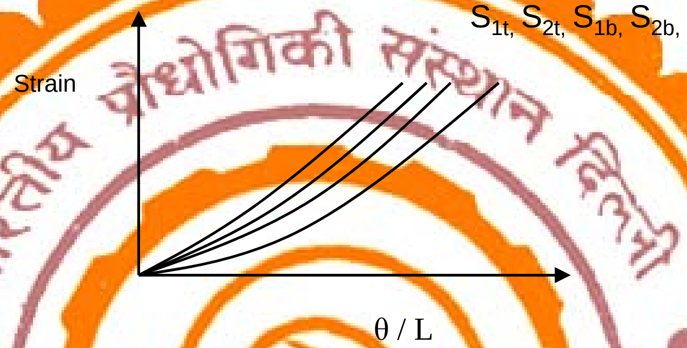
$$G = \frac{E}{2(1+\gamma)}$$

$$E = 5000\sqrt{fck}$$

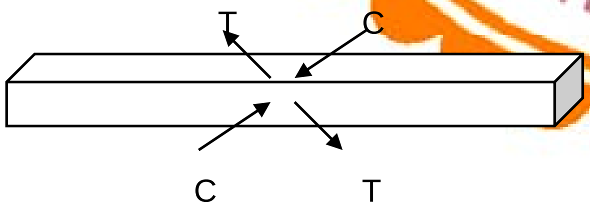
$$J = \beta b^3 a$$

$$\beta = \text{function of}\left(\frac{a}{b}\right)$$





→ Study the behavior of external strain gauges and predict the direction of principal stresses



→ Correlate with theory

2008 BATCH

2008 BATCH

2009 BATCH

2009 BATCH (Failure at: 45 kN)

CEL 232 CONCRETE MATERIALS & DESIGN

NON- DESTRUCTIVE EVALUATION (NDE) OF CONCRETE

Concrete Strength :
Very important for management since all major mechanical properties of concrete are function of its strength.

Actual Structure : Strength can not be estimated directly.

NDE Methods

To determine concrete strength in actual structures in non – destructive manner, i.e without causing any damage in the structures.

However, don't yield absolute strength, since they measure some property of concrete related to strength.

Best for accessing the uniformity of quality and development of strength with time.

In this practical, two NDE techniques will be studied: rebound hammer and ultrasonic pulse velocity test

REBOUND HAMMER

Also called Schmidt Hammer

Measures the hardness of a material surface by the rebound of a standard ball after an elastic impact against the surface, the mass being released from a standard precompressed spring.

Rebound no $= \frac{\text{Distance traveled after impact}}{\text{Original distance}} \times 100$

Should take average of 10 -12 reading

Rebound no. has been calibrated against Compressive strength.

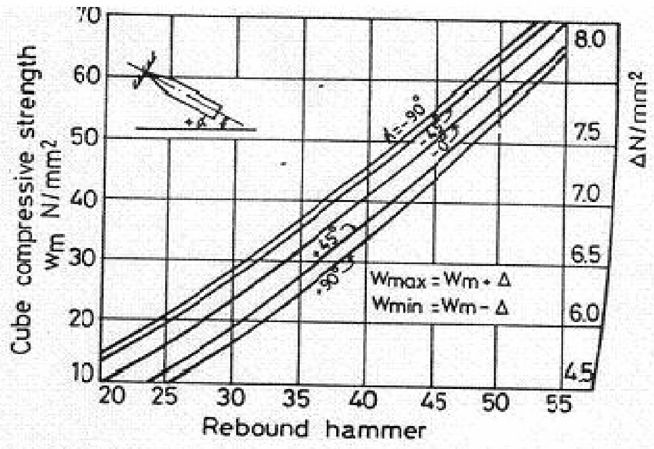
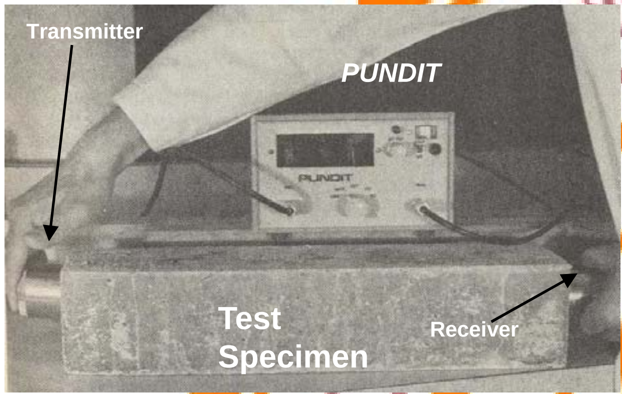


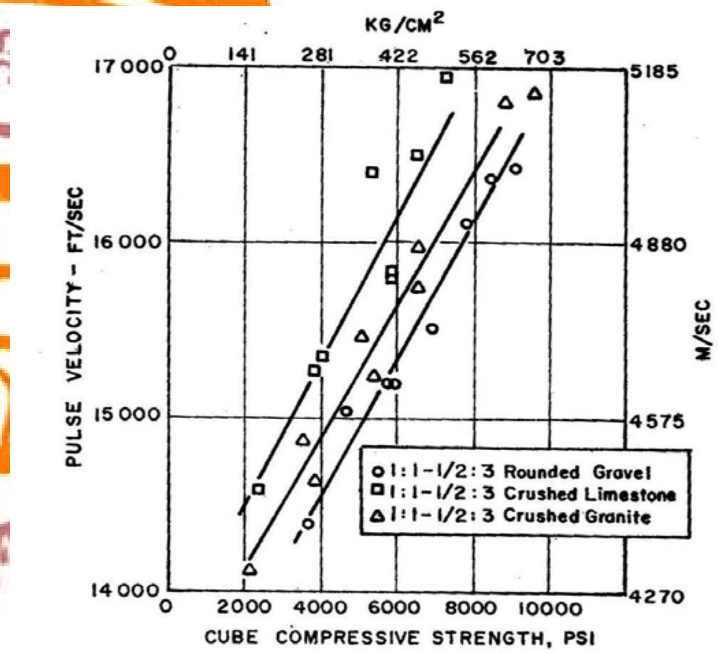
FIG. 3 CUBE COMPRESSIVE STRENGTH IN N/mm^2 PLOTTED AGAINST THE REBOUND NUMBER

B.Bhattacharjee **(2008), "**NON-DESTRUCTIVE TESTING OF CONCRETE AND CONDITION ASSESMENT",

NATIONAL WORKSHOP ON STRUCTURAL HEALTH MONITORING, NON-DESTRUCTIVE EVALUATION ANDRETROFITTING OF STRUCTURES, 07-08 MARCH 2008, INDIAN INSTITUTE OF TECHNOLOGY DELHI, page 11-57

ULTRASONIC PULSE VELOCITY (USPV) TEST





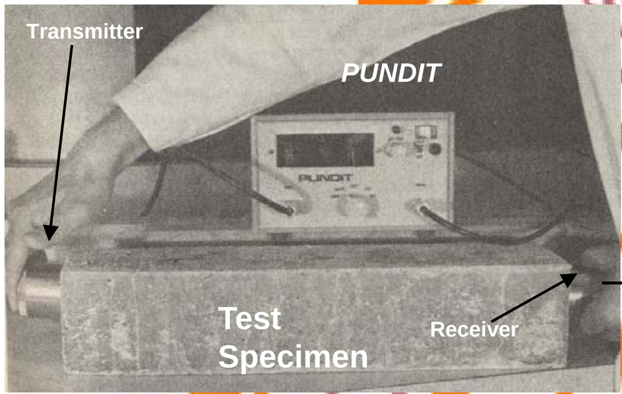
Based on velocity of sound, measured by determining the time travel of an electronically generated longitudinal wave through concrete.

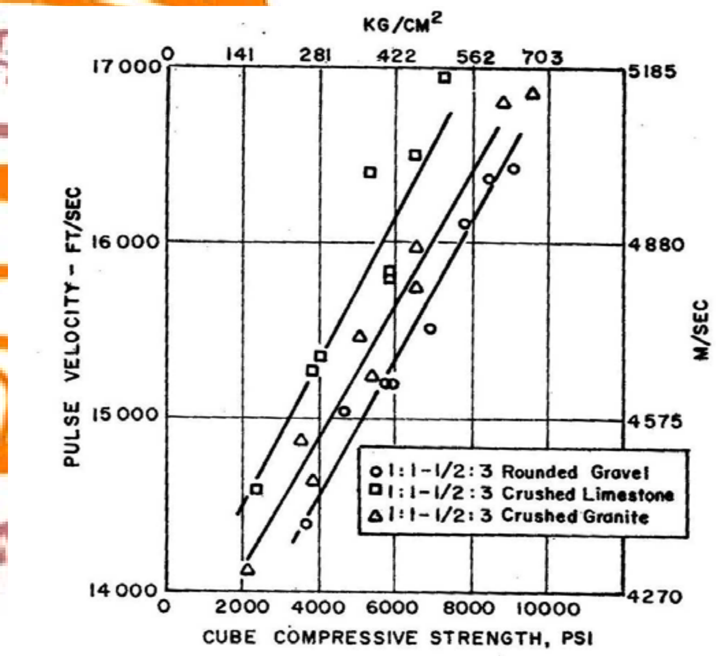
$$v = \sqrt{\frac{E}{\rho}\frac{(1-\nu)}{(1+\nu)(1-2\nu)}}$$

E, ρ : Continuity of solid phase, porosity, micro cracks

ν Give estimate of E→ Gives on estimate of the strength of concrete.

ULTRASONIC PULSE VELOCITY (USPV) TEST





AVAILABLE CORRELATIONS:

$$S = A + Bv^{n} \qquad S(MPa) = 2 + 0.1v^{4} \qquad (\text{v in km/s})$$

S (MPa) = 52.25 v – 210.575 **(v in km/s)**

Malhotro, V.M (1976) Testing Hardened concrete: Non- destructive Methods,

ACI Monograph 9

Should take average of 3-5 reading

CEL 232 CONCRETE MATERIALS & DESIGN

TENSILE STRENGTH OF CONCRETE

Tensile strength :

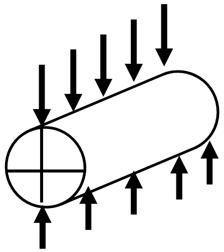
Important for liquid retaining structures, pavements, airport runways.

$$\frac{\sigma_t}{\sigma_c}$$ is between 0.07 to 0.11 (lesser for higher grades)

CEL 232 CONCRETE MATERIALS & DESIGN

TENSILE STRENGTH OF CONCRETE

Split Cylinder Test



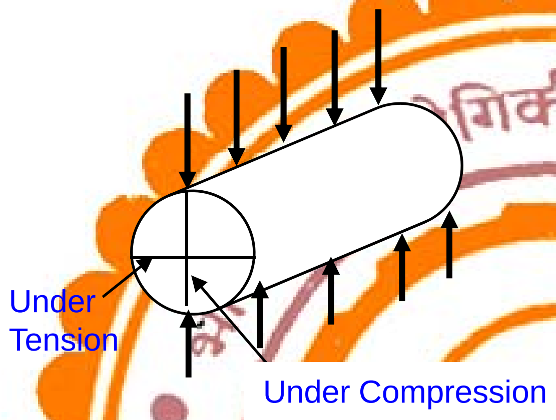
Direct Tension Test (DTT)

Flexural Tension Test

DRAWBACKS

- Difficult in making suitable fixtures
- Scatter of data

SPLIT CYLINDER TEST



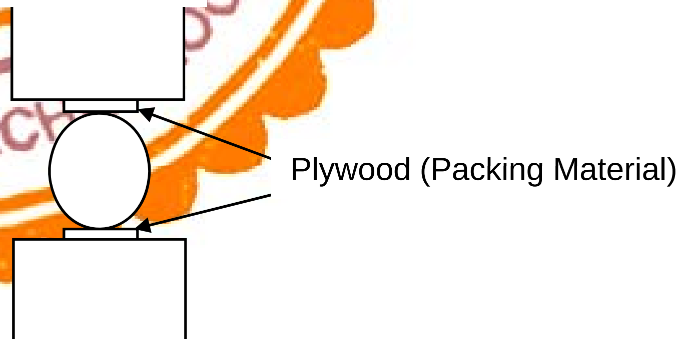
$$\sigma_t = \frac{2P}{\pi L D}$$

Tensile strength by this test: 1.05 to 1.15 of the strength from direct tension test (DTT).

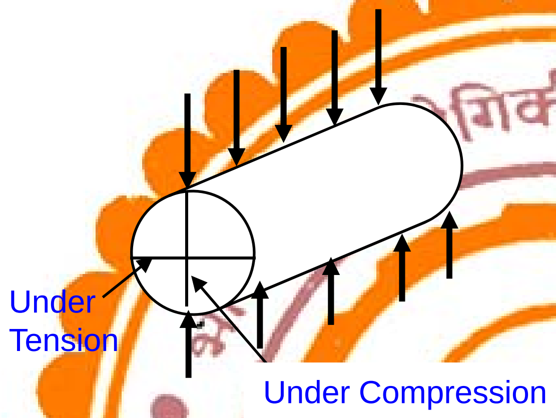
Reasons:

- **DTT – Accidental eccentricity**
- **DTT – Entire specimen subjected to max stress.**

Experimental Set up



SPLIT CYLINDER TEST



Loading Rate

$$\sigma_t = \frac{2P}{\pi LD} = 7kg/cm^2/\min$$

$$P = 3.5\pi LD kg/\min$$

S No.	P (kN)	σ_t (MPa)	Mode of Failure

FLEXURAL TENSION TEST

$$M = \frac{P}{2} \times \frac{L}{3} = \frac{PL}{6}$$

$$Z = \frac{1}{6} bD^2$$

$$\sigma_t = \frac{M}{Z} = \frac{PL}{bD^2}$$

L =400mm
b = D = 100mm

Result is generally 1.3 to 1.8 times strength from DTT.

<u>Reasons:</u>

1. DTT – Accidental eccentricity.
2. DTT – Entire specimen under maximum stress, therefore high probability of occurrence of weak element.
3. In flexural tension test, concrete above NA prevents crack propagation.
4. In flexural tension test, actual stress distribution parabolic, linear assumption over estimates tensile stress.

FLEXURAL TENSION TEST

Loading Rate $\sigma_t = \dfrac{PL}{bD^2} = 7kg/cm^2/\min$

S No.	P(Failure)	(Kg/Cm2)	(N/mm2)	Failure Mode
		To be calculated to nearest 0.5 Kg/cm2		

Find the ratio of strength from the two tests.

If failure plane is between roller and first loading point:

$$M = \frac{Pa}{2} \qquad \sigma_t = \frac{M}{Z} = \frac{3Pa}{bD^2}$$

If a<11 cm results be disregarded.

CEL 232 CONCRETE MATERIALS & DESIGN

BEHAVIOUR OF RC SLAB

CEL 232 CONCRETE MATERIALS & DESIGN

BEHAVIOUR OF RC SLAB

TEST PROCEDURE

1. Note for the SLAB: dimensions L, b, D, reinforcement details, location of strain gauges (internal & external).

2. Load the specimen statically and observe and mark the cracks. Note P & Δ (deflection), ε_1, ε_2 (strains) etc.

3. Plot w (UDL intensity) Vs Δ and w Vs strains

4. Calculate w_u theoretically and compare with experimental value

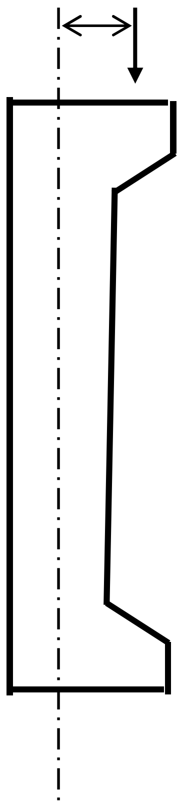
5. Note and sketch failure pattern

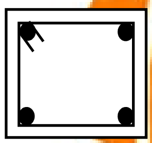
2008 BATCH

2009 BATCH (Failure at: 90 kN)

CEL 232 CONCRETE MATERIALS & DESIGN

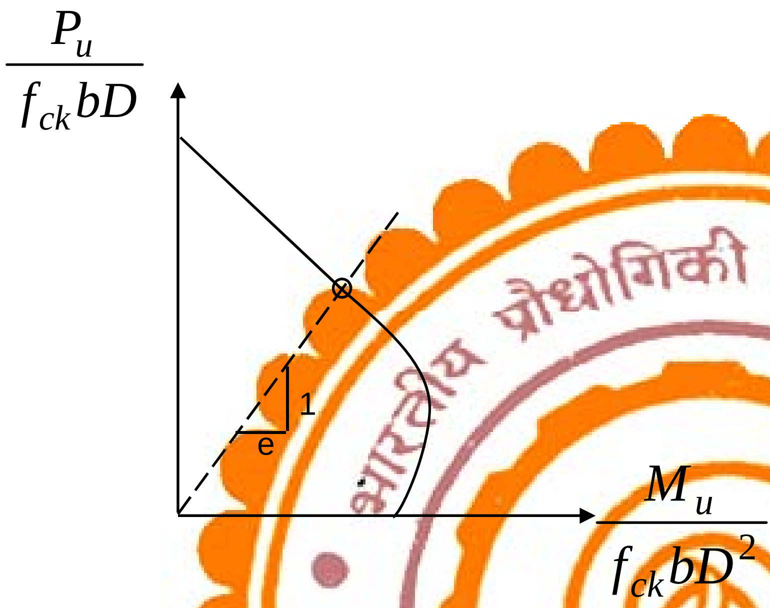
BEHAVIOUR OF ECCENTRICALLY LOADED RC COLUMN





Uniaxially eccentrically loaded column

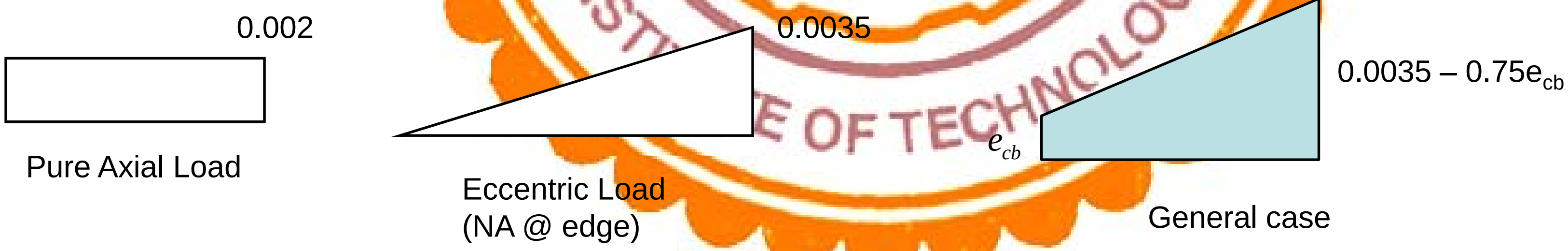
$$e = \frac{M_u}{P_u} = Known$$



$P_u = ?$

$M_u = ?$

- Compare with experimental values.
- Obtain failure strains and plot load Vs strains.



2009 BATCH

Failure at: 490 kN)

2009 BATCH

TEST PROCEDURE

1. Note for the SLAB: dimensions L, b, D, reinforcement details, location of strain gauges (internal & external).

2. Load the specimen statically and observe and mark the cracks. Note P & Δ (deflection), ε_1, ε_2 (strains) etc.

3. Plot w (UDL intensity) Vs Δ and w Vs strains

4. Calculate w_u theoretically and compare with experimental value

5. Note and sketch failure pattern

CEL 232 CONCRETE MATERIALS & DESIGN

YOUNG'S MODULUS OF CONCRETE

Tangent modulus

$$E_t = \left(\frac{d\sigma}{d\varepsilon}\right)_{\varepsilon=\varepsilon_1}$$

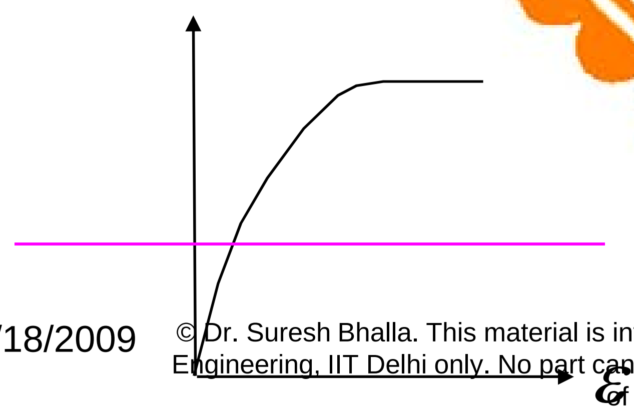
Initial Tangent modulus

$$E_{to} = \left(\frac{d\sigma}{d\varepsilon}\right)_{\varepsilon=0}$$

Secant modulus

$$Es = \left(\frac{\sigma}{\varepsilon}\right)_{\varepsilon}$$

Difficult to determine precisely



- **Easy to determine. Stress-strain curve is almost linear till 30-40% of ultimate stress, if the specimen is loaded a number of times.**
- **Varies least with increasing loads**
- **Adopted by most codes**
- **But hysteresis effects should be eliminated (micro cracks develop during first loadings).**

TEST PROCEDURE

1. Load three specimens (cylinder) till failure to determine average failure stress.

2. Load the test specimen at 140kg/cm^2/min till one-third of the failure stress.

3. Record strain at an interval of 1t, both during loading and unloading.

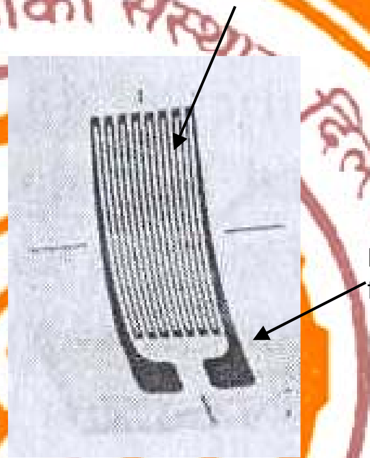
4. Repeat step 3 another 15 times, but without recording.

5. Load finally again and make recording (17th cycle)

6. Load the specimen till failure (recording not necessary), just final failure load be noted.

STRAIN MEASUREMENT

Electrical Strain Gauge (ESG)



$$\frac{\Delta R}{R} = S_g \varepsilon$$

R = 120 Ω (measure exactly)

S_g = Gauge factor (note from data sheet)

STRAIN TO BE MEASURED USING DIGITAL MULTIMETER