18th INTERNATIONAL CONFERENCE ON RHEOLOGY OF BUILDING MATERIALS-REGENSBURG

EFFECT OF STEEL FIBRES ON THE RHEOLOGY OF SELF COMPACTING CONCRETE

Dr. P.T. Santhosh Kumar
Structural Engineer, Granite Construction Company, P.O.Box 842, Abu Dhabi, U.A.E.

SELF COMPACTING CONCRETE(SCC)?

- compacts by its self weight.
- high deformability and segregation resistance.
- relatively high powder content than ordinary concrete.
- low yield stress and adequate viscosity.
- aggregates float in a medium of paste due to buoyancy.

- developed in 1988 in Japan by Prof. Okamura.
- to achieve durable concrete structures.
- avoid white finger syndrome.
- reduces noise pollution.
- usefulness in the highly congested reinforcement zones especially in earthquake resistant structures.
- wide application in precast industry.
- usefulness in the rehabilitation industry .

WHY STEEL FIBRES?

To improve:

- Ductility.
- first crack load.
- post crack resistance.
- energy absorption capacity.
- blast resistance.
- the shrinkage resistance.

METHODS FOR OBTAINING SCC

Okamura(1997)

- Coarse aggregate content is fixed at 50 % of the solid volume.
- Fine aggregate content is fixed at 40 % of the mortar volume.
- Water powder ratio (w/p) shall be between 0.9 to 1.0.
- w/p ratio and superplasticizer dosage shall be adjusted to obtain SCC.
- Check for self compactability using U- tube proposed by Tatarsal.

Okamura and **Ouchi** (2003)

- Gave detailed description on the development and application of self-compacting concrete. They have stated that the degree of packing of coarse aggregate in SCC is approximately 50% and that of fine aggregate in mortar is 60%.

- The viscosity of paste in SCC must be high enough to inhibit segregation. Higher viscosity can be achieved by adopting a lower w/p ratio.

- Concrete can be regarded as self-compactable if the filling height of 300 mm is achieved in the U-flow test or the box test.

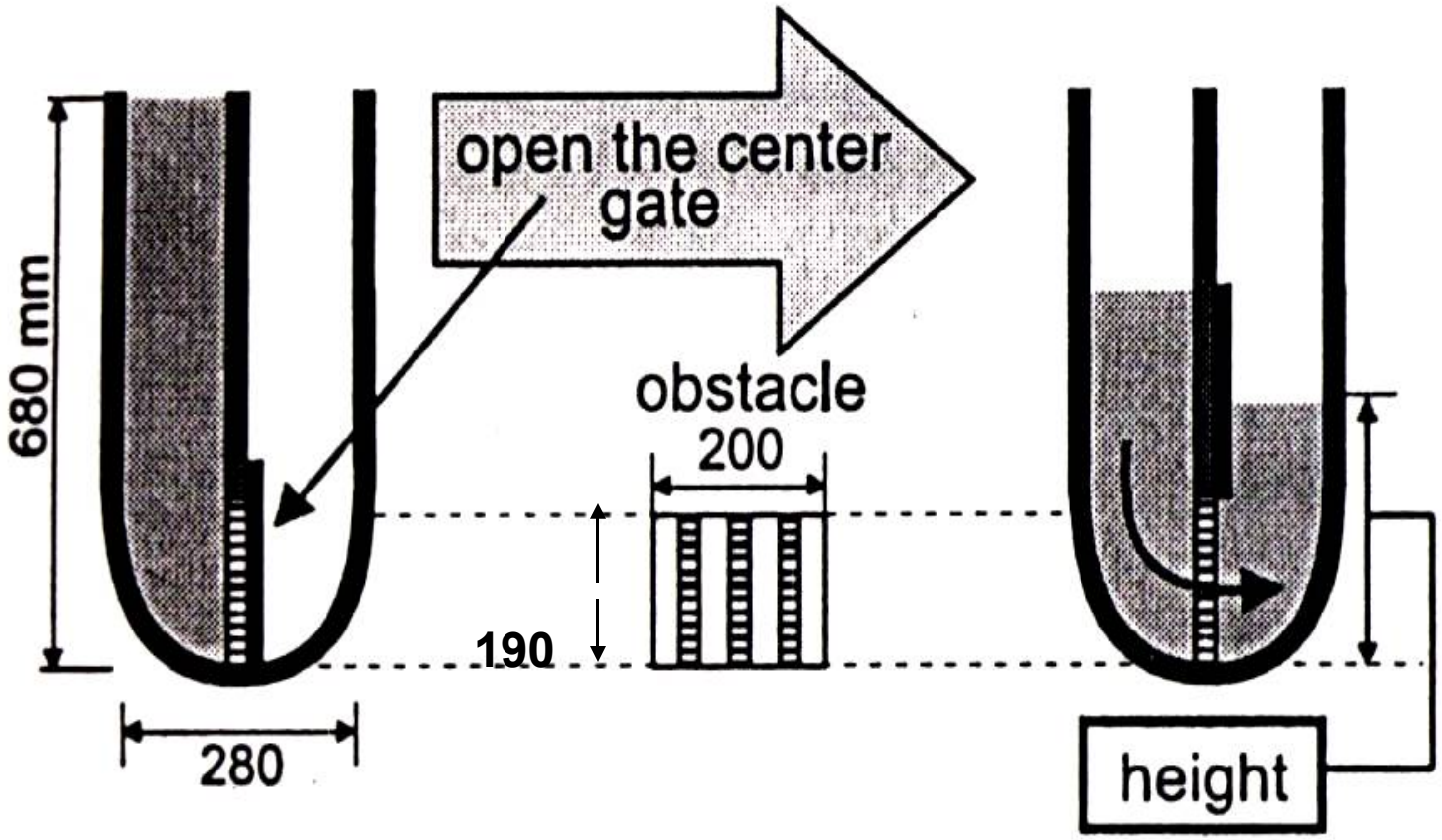
- If the concrete is judged to be having insufficient self-compactability through U-flow test, the cause has to be detected quantitatively so that the mix proportion can be adjusted.

- Slump-flow and funnel tests have been proposed for testing deformability and viscosity, respectively.

EFNARC (2002)

- Water content shall be from 180 to 200 kg/m^3.
- Total powder content shall be from 400 to 600 kg/m^3.
- w/p ratio shall be from 0.8 to 1.1.
- Coarse aggregates shall be from 0.28 to 0.36 m^3.
- Fine aggregate balances the volume of other constituents.

Fig. 1U-tube apparatus



Height shall be between 300-340 for SCC.

All dimensions in mm.

Fig. 2 U-tube test

Fab: 2002

Fig. 3 V- Funnel

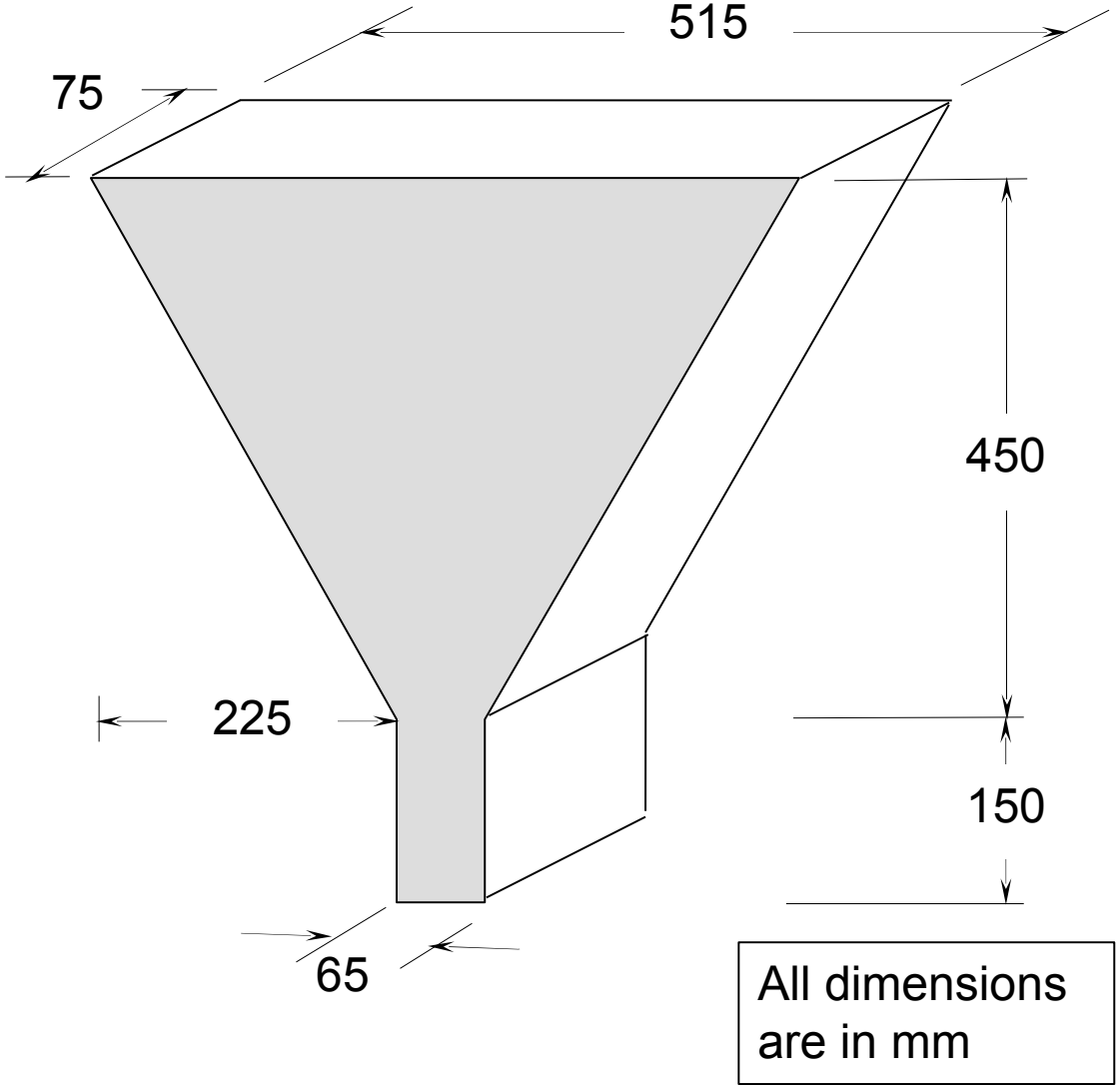
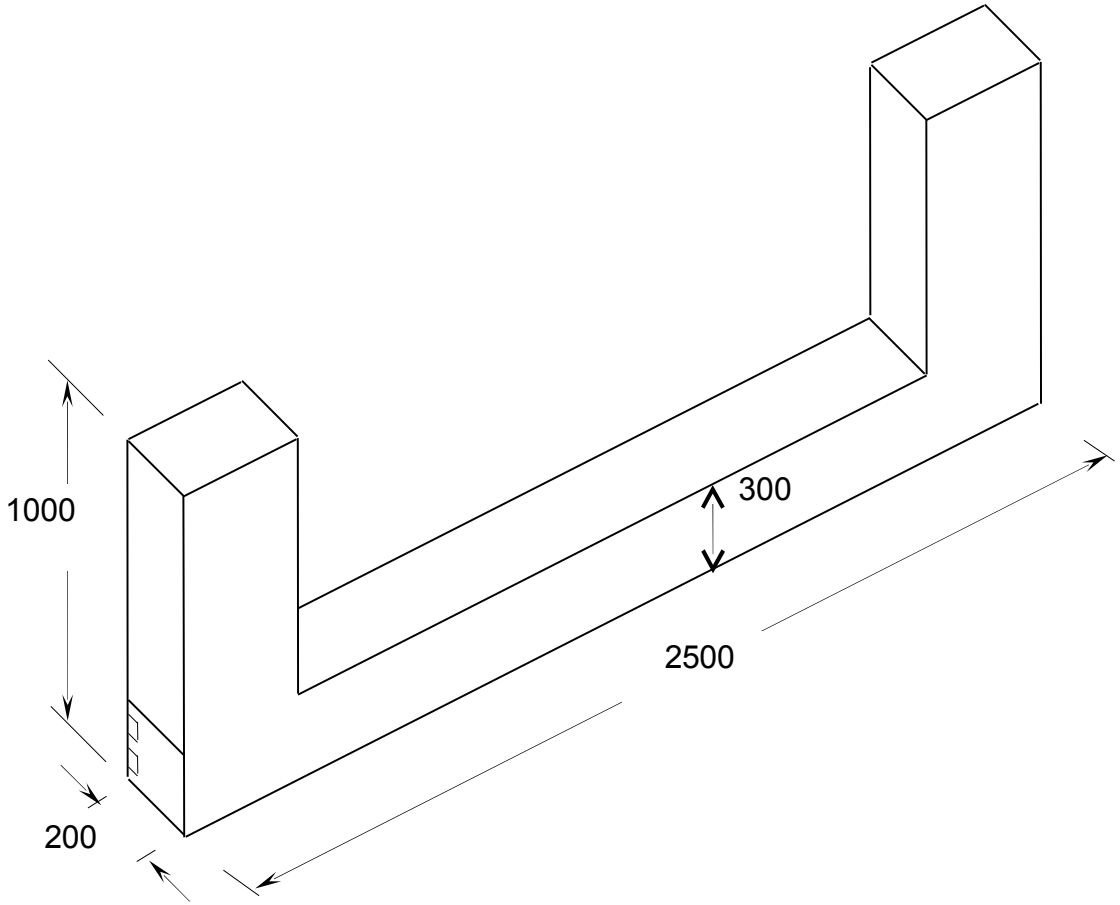
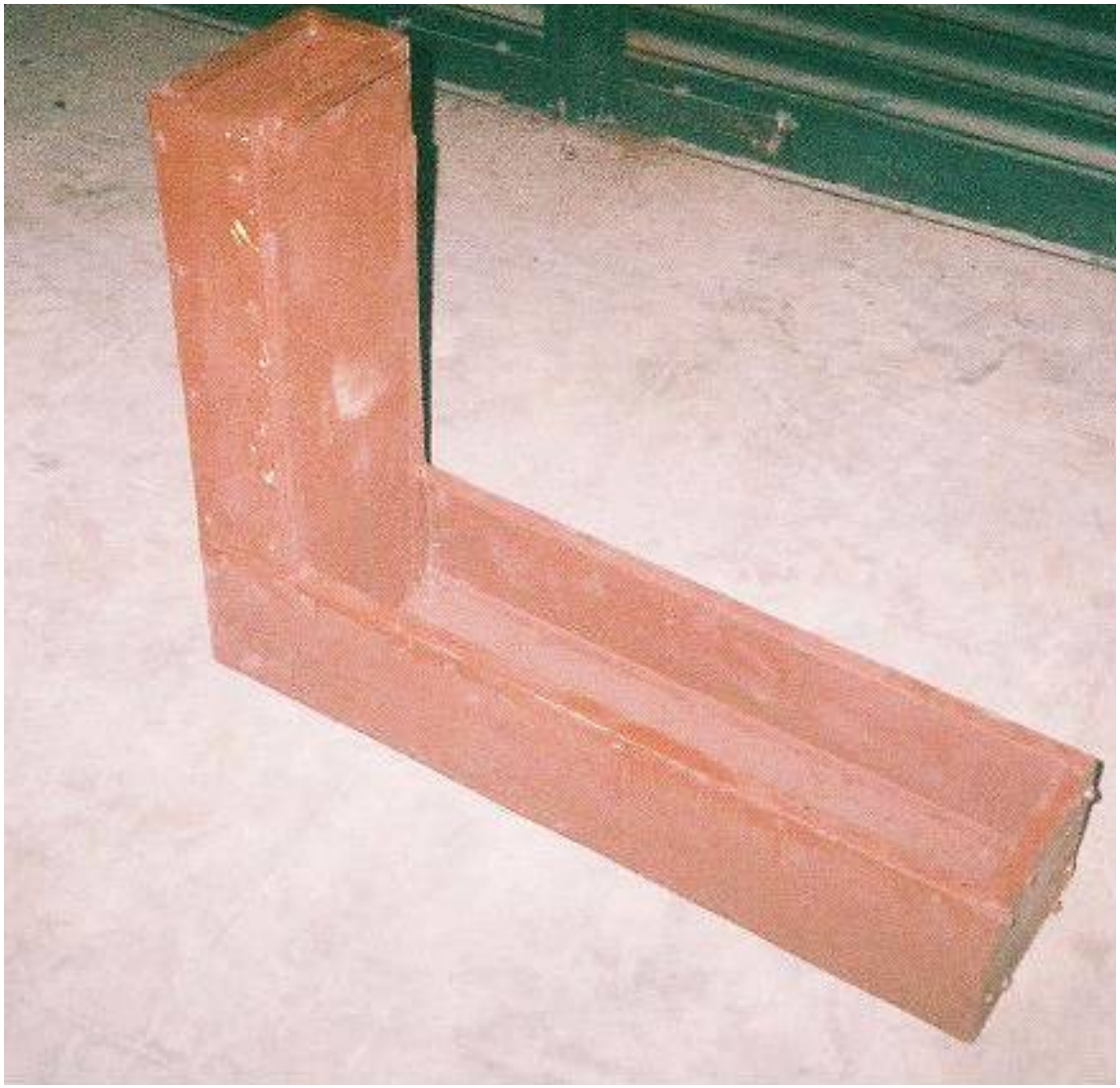


Fig. 4 Diagram of V-funnel

Fig. 5 Equipment for acceptance test of SCC at site


1000
300
2500
200

Big U-tube for full scale structural elements



L-Box

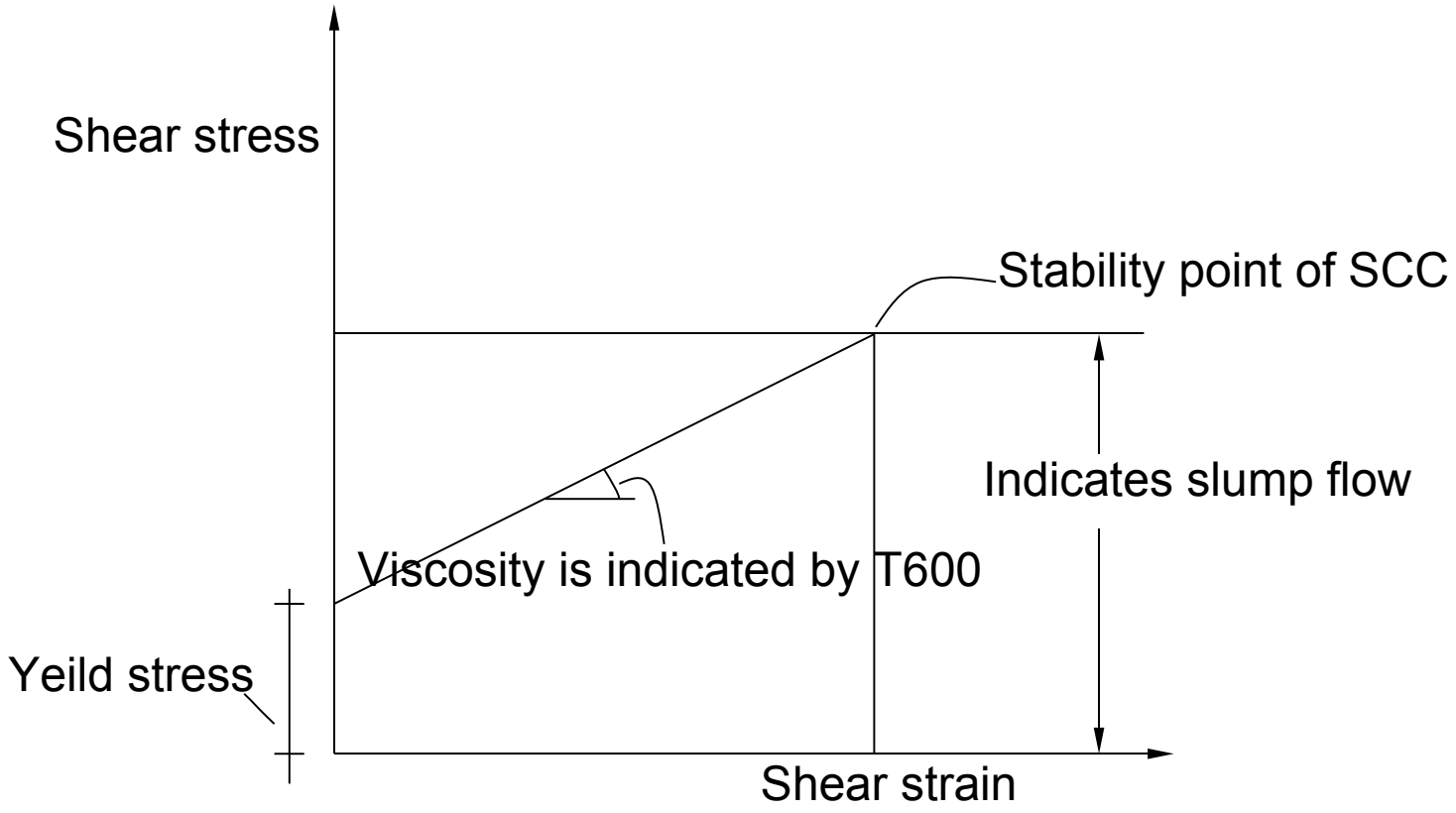
Mini U-tube

Mini slump cone test

CRITERIA FOR SELF COMPACTABILITY

- U-tube value between 300 to 340 mm
- If the mix fails U-tube test, check whether yield stress (deformability) or viscosity of the mix is the deficient factor. Slump flow test checks whether the yield stress is sufficiently low and V-funnel test checks whether the viscosity is sufficient for the coarse aggregates to float but not segregating or not flowing with sufficient speed. These conditions will satisfy when:
- Slump flow value between 600-800 mm
- V- funnel time between 7-20 s

SIMILARITY OF SLUMP FLOW AND YEILD STRESS AND VISCOSITY AND T600



MATERIALS USED

Sl. No.	Materials	Description
1	Cement	53 grade OPC
2	Fine aggregate	Natural sand with fineness modulus 2.15 and confirming to zone III of IS: 383- 1970
3	Coarse aggregate	Maximum size 16 mm having fineness modulus 7.0
4	Fly ash	Lignite based
5	Silica fume	-
6	Water	Potable
7	Superplasticizer	SNF
8	Viscosity modigying agent	Polysaacharide based
9	Steel fibres	0.91 mm diameter galvanized mild steel with aspect ratios of 15, 25 and 35.

SCC MIX PROPORTION

Particulars	kg/m^3
Cement	508
Fly ash	60
Coarse aggregate	707
Fine aggregate	760
Water	216
Silica fume	32
Superplasticizer	6.0
VMA	0.022

STEEL FIBRE REINFORCED SELF COMPACTING CONCRETE (SFRSCC)

- Variables:

  i. Aspect ratio of steel fibres 15, 25, 35 and 45 with diameter of 0.91 mm.
  (Length of fibres is 14, 23 and 32 mm respectively)

  ii. Volume fraction of steel fibres ranging from 0.25 to 1.5 % in steps of 0.25 %.

Fresh properties of SCC with fibres

A_f	V_f	Slump flow (mm)	V-funnel time (s)	U-tube Value (mm)	L- Box value	T_{600}	Remarks
0	0	730	9	340	0.9	9	SCC
15	0.25	720	10	330	0.85	10	SCC
	0.5	700	11	320	0.85	10	SCC
	0.75	690	12	318	0.8	13	SCC
	1	610	38	280	0.7	39	Not SCC
	1.25	540	46	Blockage	Blockage	48	Not SCC
	1.5	500	66	Blockage	Blockage	68	Not SCC
25	0.25	718	11	328	0.85	12	SCC
	0.5	690	11	316	0.85	12	SCC
	0.75	680	13	315	0.8	14	SCC
	1	600	36	270	0.78	38	Not SCC
	1.25	530	48	Blockage	Blockage	55	Not SCC
	1.5	480	75	Blockage	Blockage	80	Not SCC

35	0.25	715	11	325	0.88	12	SCC
	0.5	680	12	310	0.85	13	SCC
	0.75	675	12	308	0.8	12	SCC
	1	590	45	266	0.65	54	Not SCC
45	0.75	580	35	Blockage	Blockage	33	Not SCC

Self compactability was maintained up to an aspect ratio of 35 and volume fraction of 0.75 %.

Application of SFRSCC to beam-column joint

Variable considered is the volume fraction of steel fibres (0, 0.25, 0.5 and 0.75 %)

Fig. 6 Reinforcement details of beam-column joint

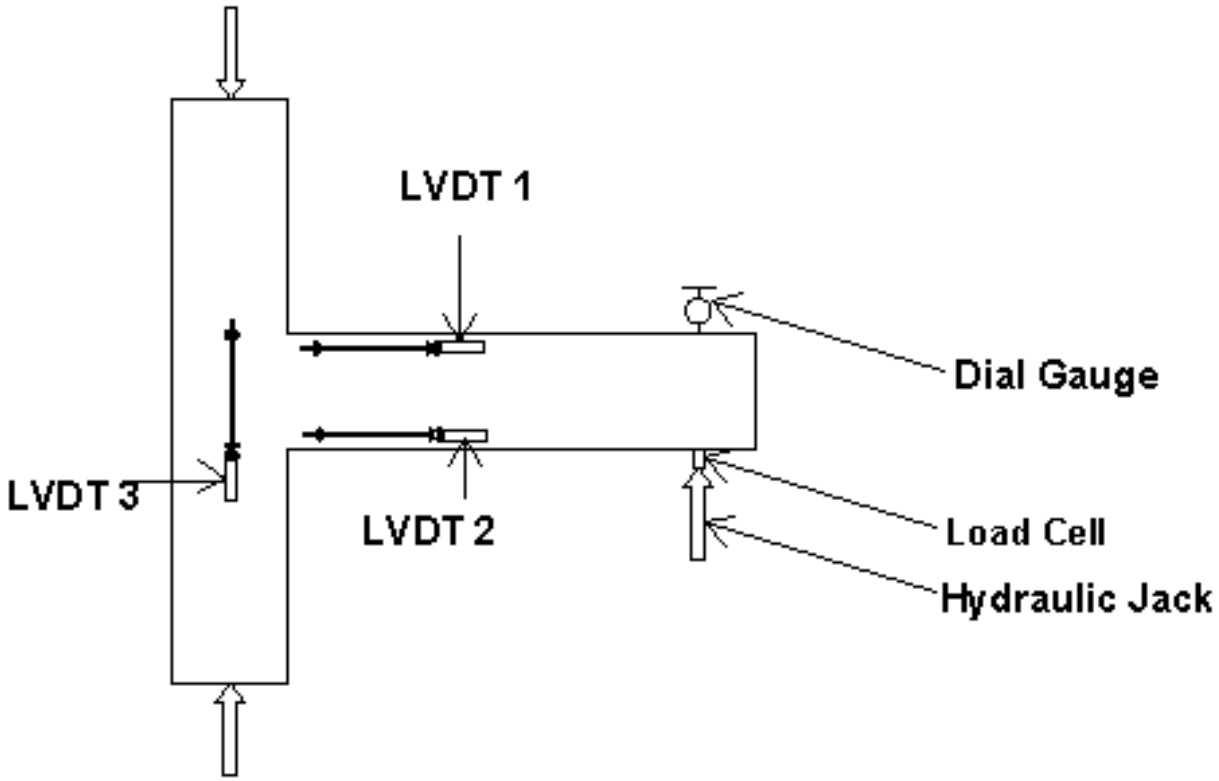


Fig. 7 Schematic diagram of test set up

Fig. 8 Test set up

Fig. 9 Failure pattern of beam-column joint with V_f = 0.5%

Test results of beam-column joints

Sl. No.	Specimen designation	Peak Load (Pu) kN	δ_u mm	Cube strength (MPa)
1	JV_0	32.0	20.0	63.5
2	JV_1	36.5	42.5	62.0
3	JV_2	42.5	55.0	65.7
4	JV_3	35.0	48.5	60.8

Calculation of ductility factor

IS 13920- 1993 defines curvature ductility factor as the ratio of curvature at ultimate strength (ϕ_u) to that at yield of steel (ϕ_y)

$$\phi_y = \frac{f_y}{E_s(d-n)} \qquad (1)$$

f_y = Yield stress of tensile steel

E_s = Elastic modulus of steel

d = Effective depth of the section

n = Neutral axis depth

Calculation of ductility factor

$$\frac{bn^2}{2} + (m_{12} - 1)A_{12}\left(n - d'\right) + \left(m_f - 1\right)V_f b\frac{n^2}{2} = m_{12}A_{12}\left(d - n\right) + m_f V_f b\frac{\left(D - n\right)^2}{2} \qquad (2)$$

$$\phi_u = \frac{\varepsilon_t + \varepsilon_b}{d_2} \qquad (3)$$

where

d_2 is the distance between the two LVDT's.

ε_t strains measured at the compression side using LVDT

ε_b strains measured at the tension side using LVDT

Curvature ductility factor

Sl. No.	Joint Designation	ϕ_y × 10^{-3}	ϕ_u × 10^{-3}	$\frac{\phi_u}{\phi_y}$
1	JV_0	17.6	50.1	2.9
2	JV_1	17.7	88.9	5.0
3	JV_2	17.6	104.9	6.0
4	JV_3	17.8	62.0	3.5

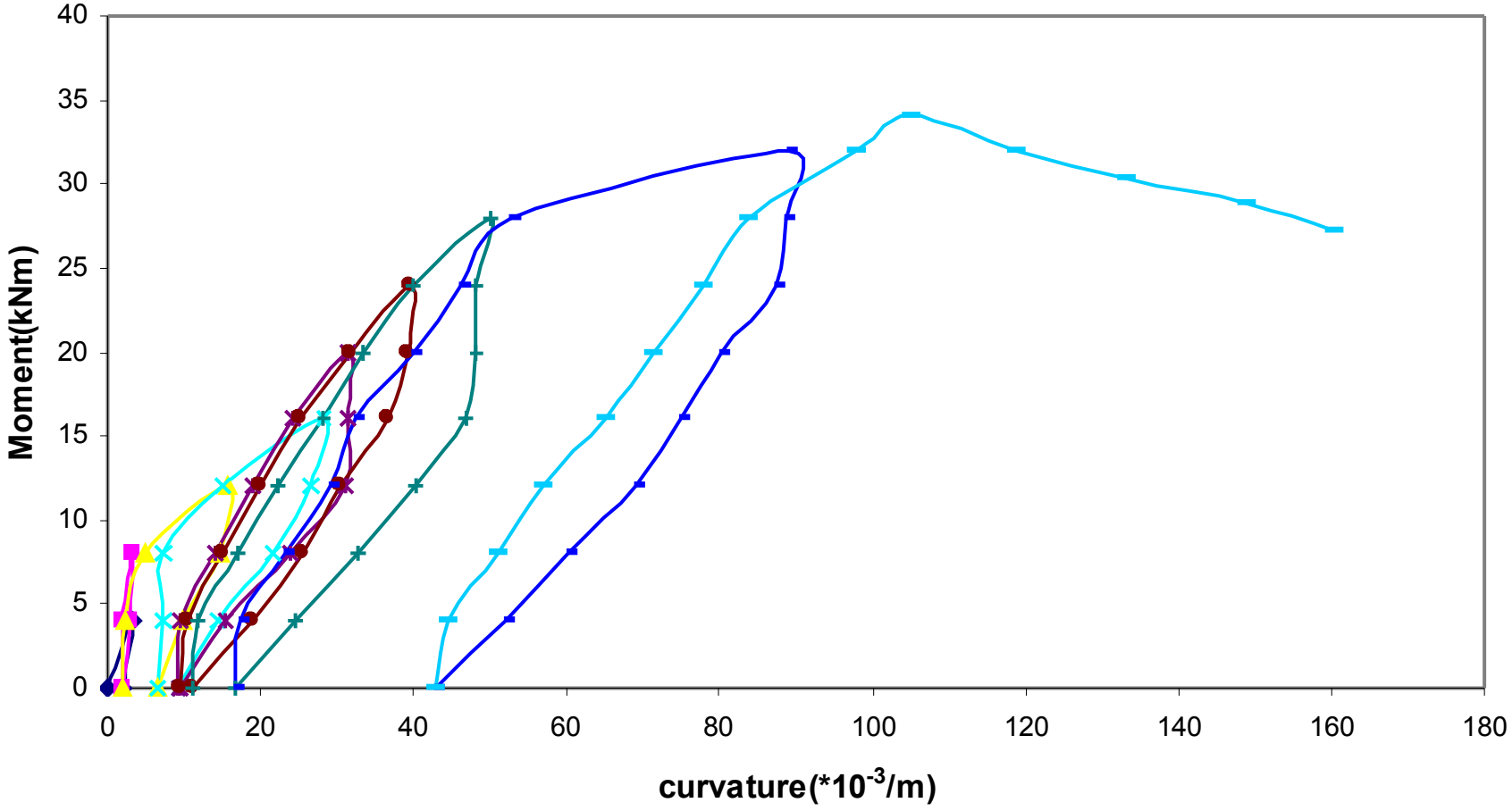


Fig. 10 Plot of moment versus curvature

CONCLUSIONS

- Addition of steel fibres to the SCC beam-column joint improves the strength and ductility of the joint.
- Even in the congested locations like beam-column joint, easy constructability could be achieved with the use of SCC.
- Deflection and curvature at peak load of SCC beam column joint significantly increased with increase of fibre content. It is true only up a volume fraction of fibres of 0.5%.

CONCLUSIONS

- Addition of steel fibres to the SCC beam-column joint improves the strength and ductility of the joint.
- Even in the congested locations like beam-column joint, easy constructability could be achieved with the use of SCC.
- Deflection and curvature at peak load of SCC beam column joint significantly increased with increase of fibre content. It is true only up a volume fraction of fibres of 0.5%.

CONCLUSIONS

- Beam-column joints with volume fractions of 0.25 and 0.50% satisfied the criteria of curvature ductility factor as given by IS: 4326 – 1993.

- When steel fibres are added to the joint, the tie spacing of the column and the stirrup spacing of the beam in the neighbourhood of the beam-column joint could be increased.

REFERENCES

2. ACI-ASCE Committee 352., “Recommendations for the design of beam-column connections in monolithic reinforced concrete structures”, ACI Structural journal, 1985, pp. 266-283.
3. GANESAN, N. and RAMANA MURTHY, J.V., “Strength and behaviour of confined steel fiber reinforced concrete columns”, ACI Materials Journal, May- June 1990, pp. 221-227.
4. OKAMURA, H. and OUCHI, M., “Self compacting concrete”, Journal of Advanced Concrete Technology, April 2003.Vol. 1, No.1, pp. 5-15.

REFERENCES

2. YIN-WEN CHAN., YU-SHENG CHEN. and YI-SHI LIU., “Development of bond strength of reinforcement steel in self-consolidating concrete”,ACI Structural Journal, Vol.100, No.4, July-August 2003.
3. _____ Indian standard code of practice for specification for coarse and fine aggregates from natural sources for concrete, IS: 383- 1970. Bureau of Indian Standards, New Delhi.
4. _____ Indian Standard Code of Practice for Plain and Reinforced Concrete, IS: 456-1978 (Reaffirmed 2000). Bureau of Indian Standards, New Delhi.

REFERENCES

2. _____ Indian standard code of practice for specification for 53 grade ordinary Portland cement. IS: 12269 -1987,Bureau of Indian Standards, New Delhi.

4. _____ State-of the-Art Report on Fibre Reinforced Concrete, ACI 544.1R-96(Reapproved 2002).