FRESH AND HARDENED PROPERTIES OF GEO POLYMER CONCRETE AND MORTAR

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PROCESS OF PREPARATION OF OPC

- OPC, the most commonly used cement manufactured by burning of large quantities of fuel, typically coal along with lime stone.

Disadvantage

- The emission of green house gases such as Co_2

WHAT IS GEOPOLYMER ?

- The term “geopolymer” was coined by Davidovits in 1978. This inorganic alumino-silicate polymer is synthesized from predominantly silicon and aluminium material of geological origin or by-product materials such as fly ash, chemicial composition of geopolymer materials are similar to Zeolite.

GEOPOLYMER – BETTER ALTERNATE FOR OPC

MAIN CONSTITUENTS

Source Materials: Fly ash, Silica fume, Slag, Rice-husk ash, Red mud, etc.

Alkaline Liquids: Sodium hydroxide with sodium silicate, Potassium hydroxide with potassium silicate.

(It is used to induce the silicon and aluminum atoms in the source materials to dissolve and form a gel)

Fly Ash Facts : Just One Ton

Just one ton of fly ash use equals:

Conserved Landfill Space

Enough for 455 days of solid waste produced by an average Indian.

Reduced CO_2 Emissions

Equal to two months of emissions from an automobile

Saved Energy

Enough to provide electricity to an average Indian home for 24 days.

FLY ASH CHECKLIST

- Workability
- Ease of Pumping
- Improved Finishing
- Reduced Bleeding
- Reduced Segregation
- Higher Strength
- Decreased Permeability
- Increased Durability
- Reduced Sulfate Attack
- Reduced Efflorescence
- Reduced Shrinkage
- Reduced Heat of Hydration
- Reduced Alkali Silica Reactivity

REST PERIOD

Definition:

" It is the time taken between casting of specimen and the commencement of curing. "

Methods of Heat Curing

- Dry Curing
- Steam Curing

CHEMICAL COMPOSITION OF CEMENT AND FLY ASH

	LOI	IR	SiO_2	Al_2O_3	Fe_2O_3	CaO	Mgo	So_3	Na_2O	Specific surface
Cement	1.65	0.76	19.33	5.66	2.66	63.07	0.36	3.38	0.14	4.51 m^2/kg
Fly Ash	2.88	0.30	54.92	23.04	6.62	3.84	2.82	0.76	0.73	3.60 m^2/kg

LOI: Loss of Ignition ; IR: = Insoluble Residue

CHEMICAL COMPOSITION OF SODIUM SILICATE SOLUTION

Composition	Na_2O	SiO_3	Water	Sp. Gravity	PH
% by mass	7.5 ± 8.5	25 ± 28	63.5 – 67.5	1.53 g/cc	neutral

MIXTURE PROPORTIONS FOR GEOPOLYMER CONCRETE

Mix	Aggregates		Fly ash (kg)	Mix proportion	NaOH solution		Sodium Silicate solution (kg)	Na_2SiO_3 / NaOH
	Sand (kg)	20mm (kg)			Mass (kg)	Molarity (M)		
M20	503.2	1078	383	1:1.31:2.81	80	14	160	2.0
M30	425.7	1012	491	1:0.87:2.06	85	14	170	2.0
M40	283.5	973.1	639	1:0.44:1.52	90	14	180	2.0

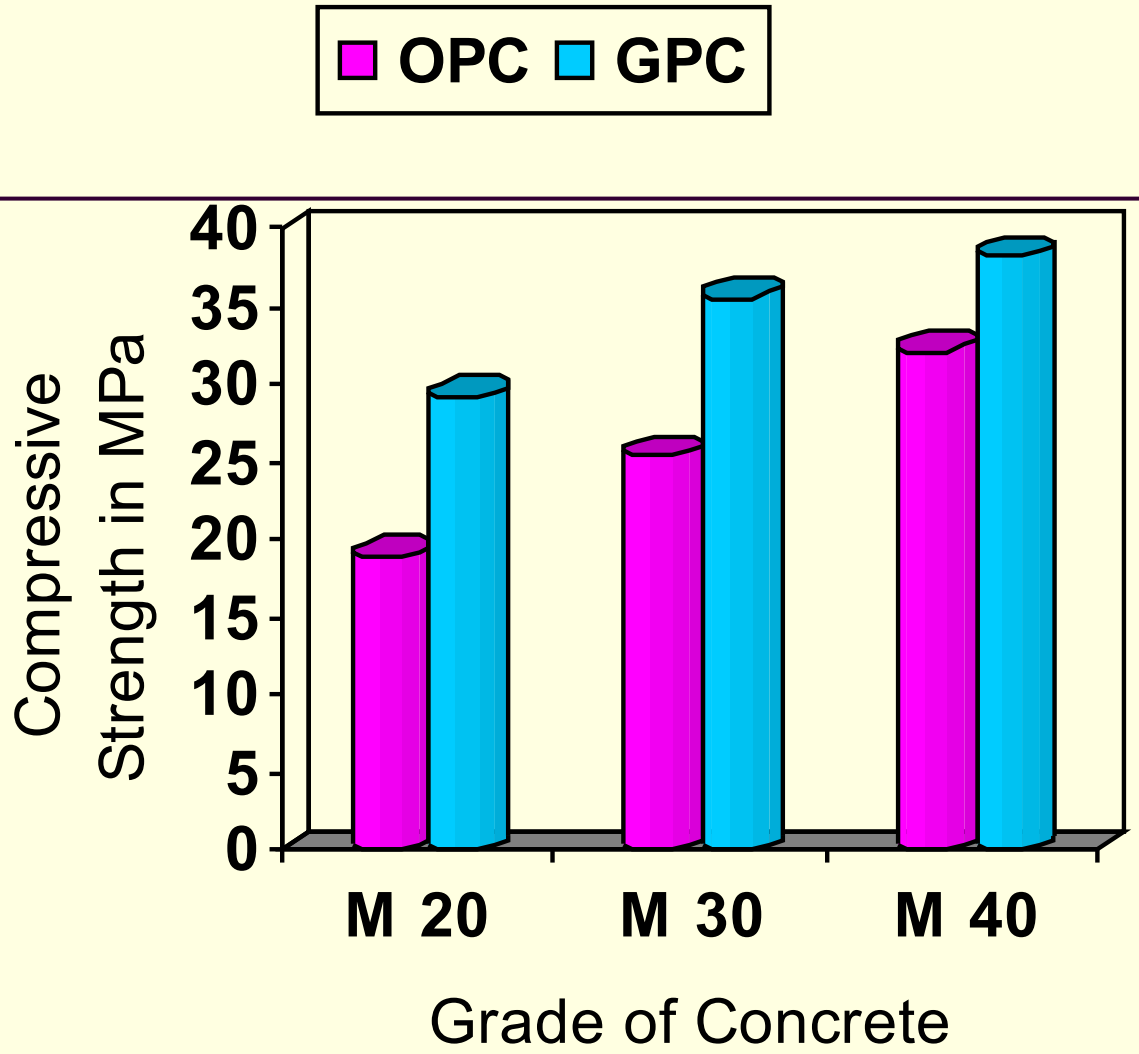
EXPERIMENTATION

Basic Properties of Geopolymer Concrete

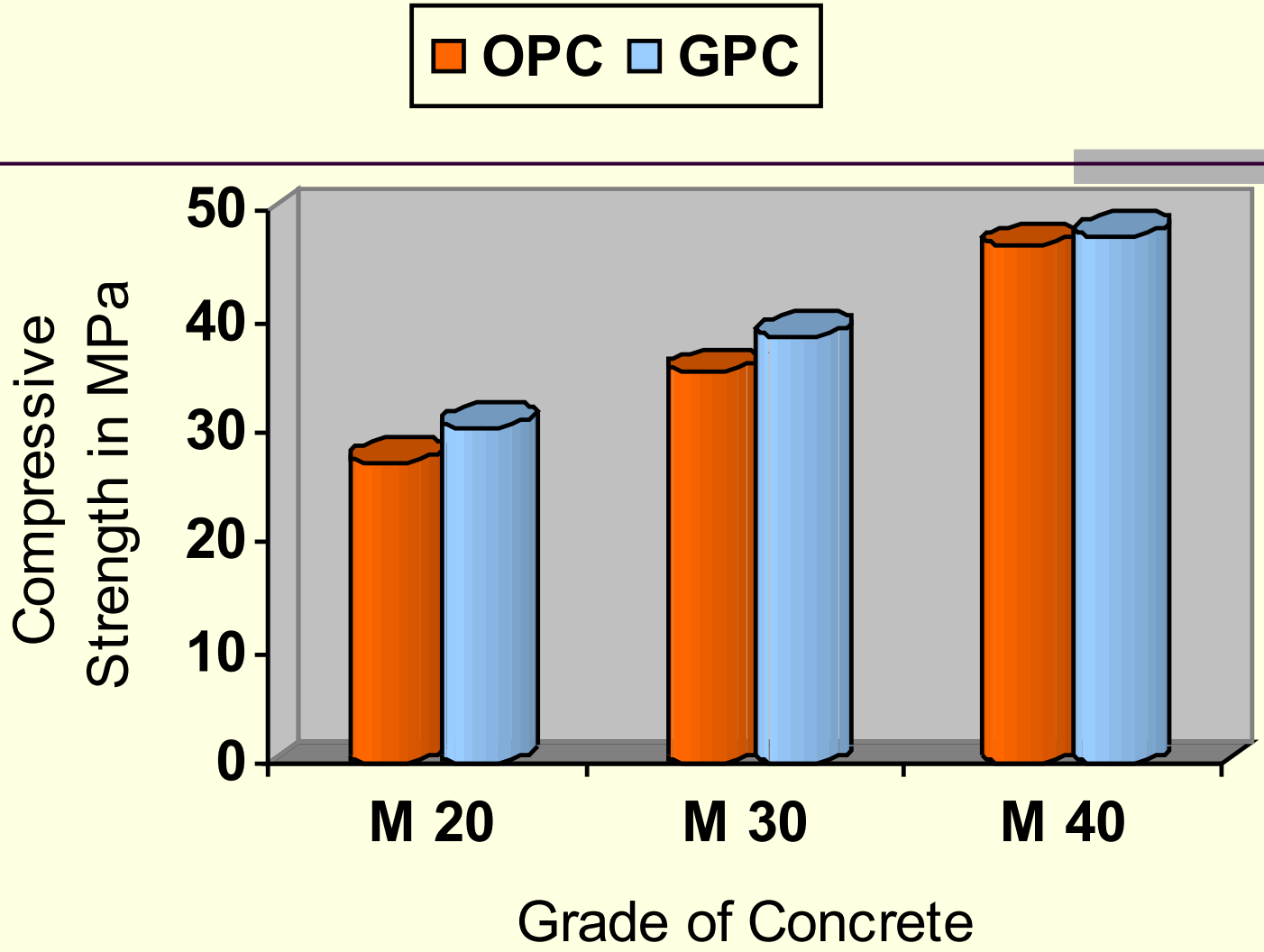
- Compressive Strength
- Split Tensile Strength
- Flexural Strength
- Static Modulus of Elasticity
- Alkalinity of Geopolymer Concrete

SLUMP, DENSITY & COMPRESSIVE STRENGTH OF NC AND GPC

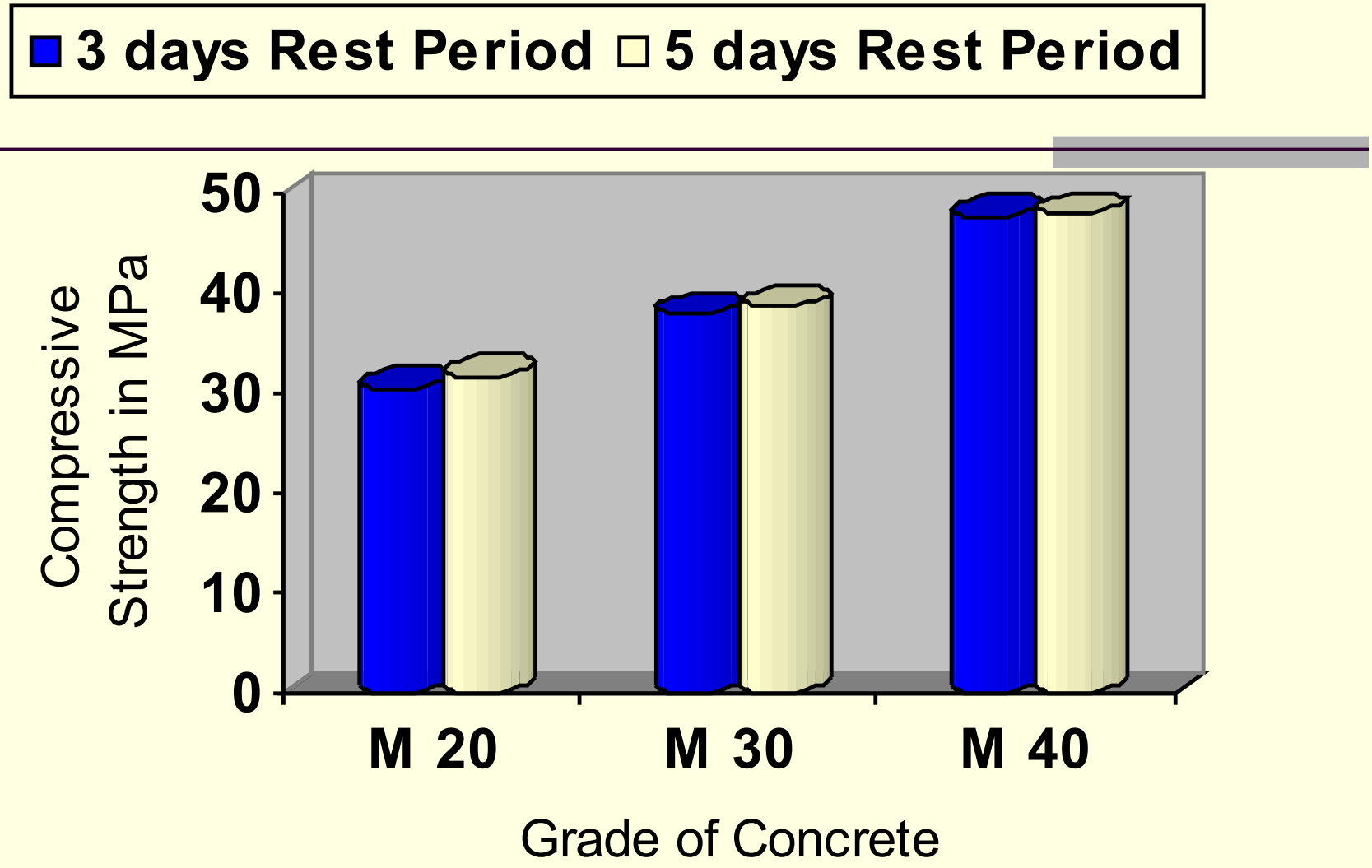
Mix	Slump (mm)	Density KN/m^3	Compressive strength MPa		Increase / Decrease	Age at test (days)	Rest period for GPC
			GPC	OPC			
GPC 20	220	23.10	29.23	18.94	54.3% Increase	7	3 Days
		22.70	30.58	27.30	16 % Increase	28	3 Days
		22.50	29.86	-----	-----	7	5 Days
		22.80	31.87	-----		28	5 Days
GPC 30	195	22.70	35.60	25.43	40% Increase	7	3 Days
		23.20	38.80	35.47	10% Increase	28	3 Days
		22.50	35.82	----	-----	7	5 Days
		22.60	38.10	----	-----	28	5 Days
GPC 40	190	23.50	38.23	32.12	20% Increase	7	3 Days
		23.00	47.85	46.96	2% Increase	28	3 Days
		23.60	42.96	----	-----	7	5 Days
		23.10	48.10	----	-----	28	5 Days



Compressive strength of OPC and GPC @ 7 days



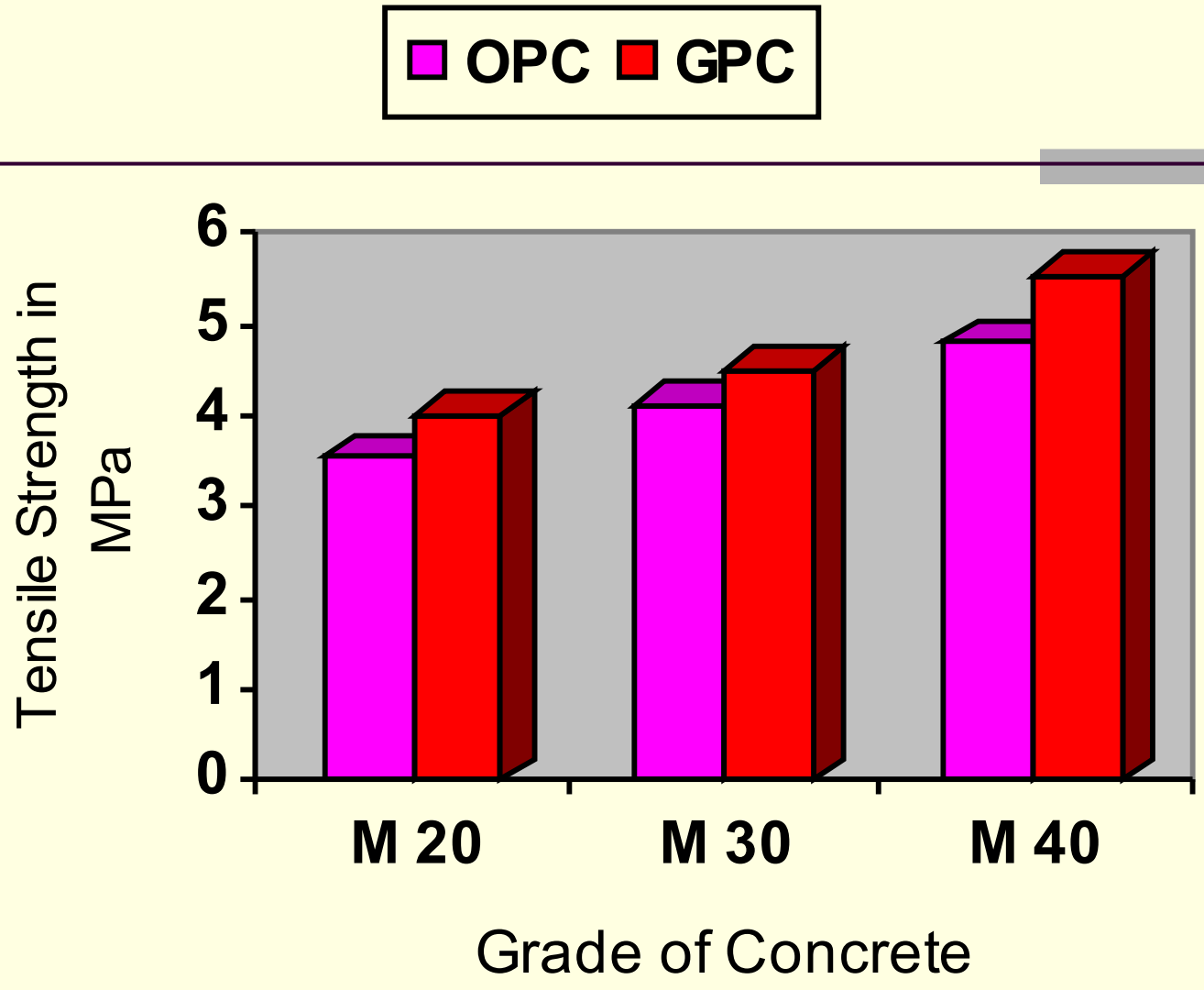
Compressive Strength of OPC and GPC @ 28 days



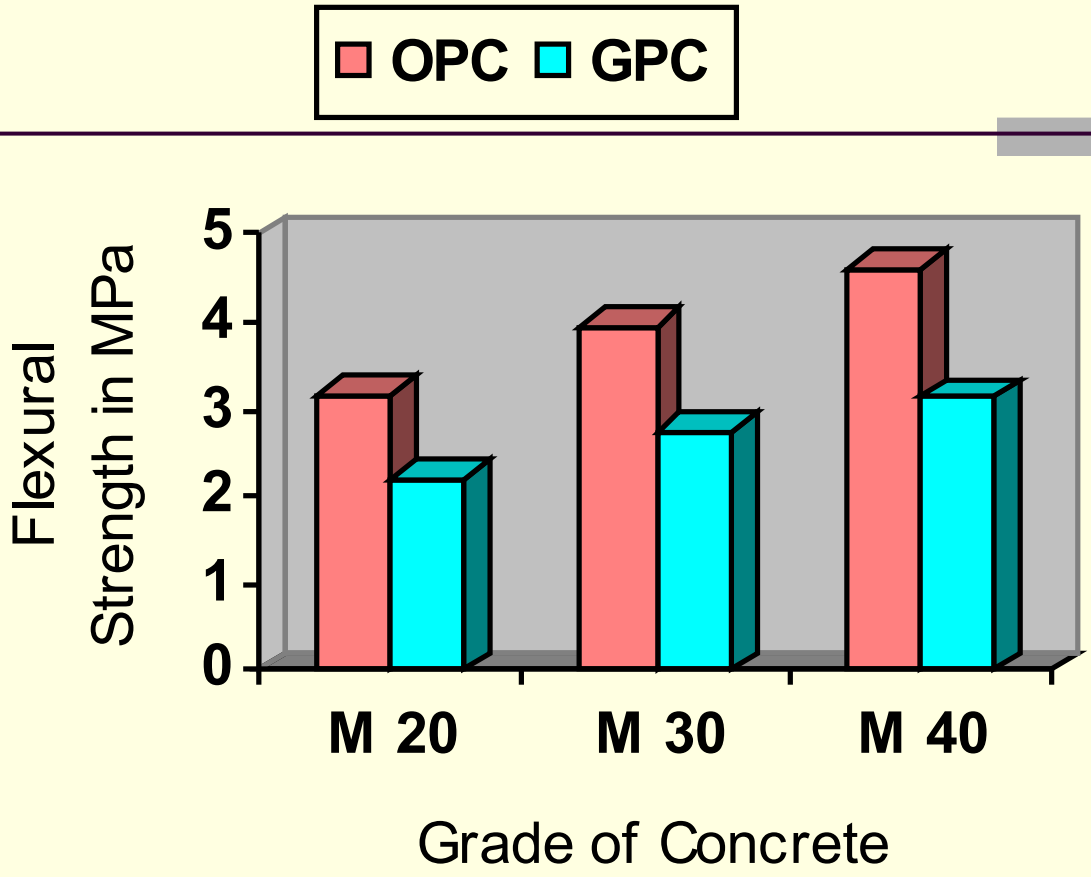
Compressive Strength of GPC @ 3 days and 5 days Rest Period

SPLIT TENSILE STRENGTH OF NC AND GPC @ 28 DAYS WITH 5 DAYS REST PERIOD

Mix	Tensile Strength in N/mm²		Increase/Decrease
	GPC	OPC	
M20	4.02	3.54	14% Increase
M30	4.50	4.10	10% Increase
M40	5.53	4.80	16% Increase



Tensile Strength of OPC and GPC @ 28 days



Flexural Strength of OPC and GPC @ 28 days

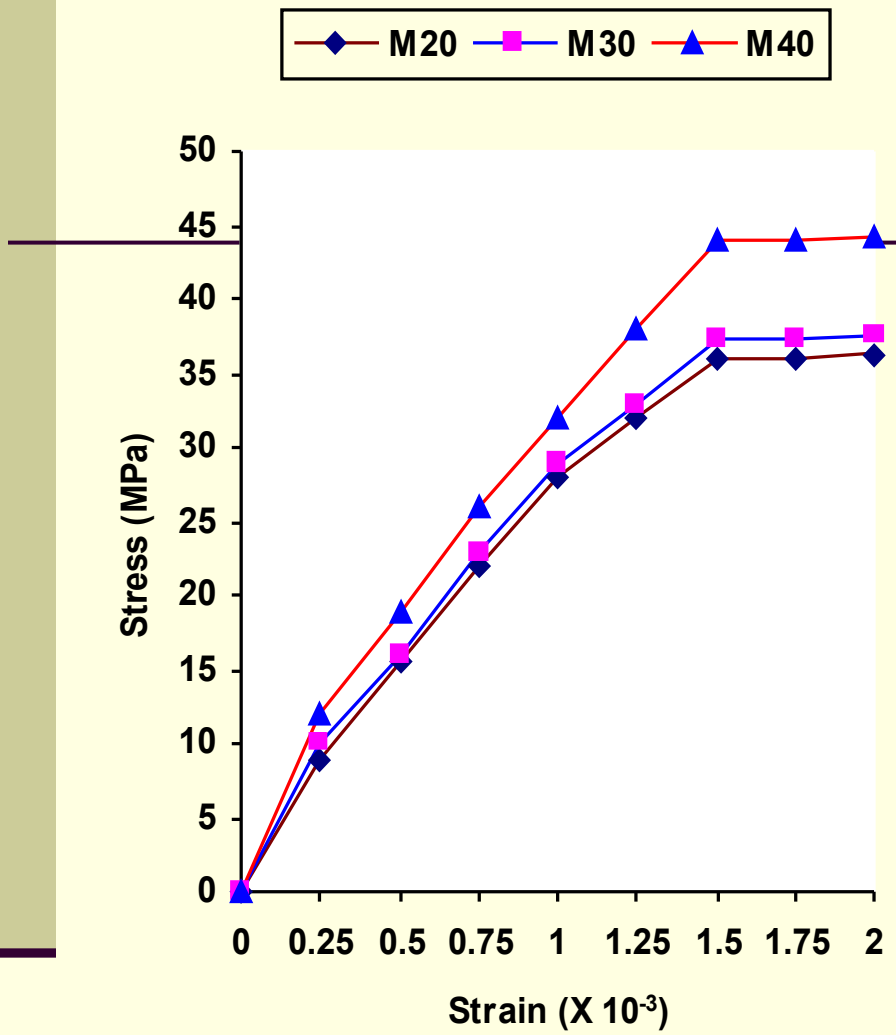
STATIC MODULUS OF ELASTICITY

Mix	OPC		GPC	
	σ N/mm²	E GPa	σ N/mm²	E GPa
GPC 20	35.9	23.9	32.0	21.9
GPC 30	37.30	28.6	38.4	26.7
GPC 40	44.0	30.8	42.4	28.9

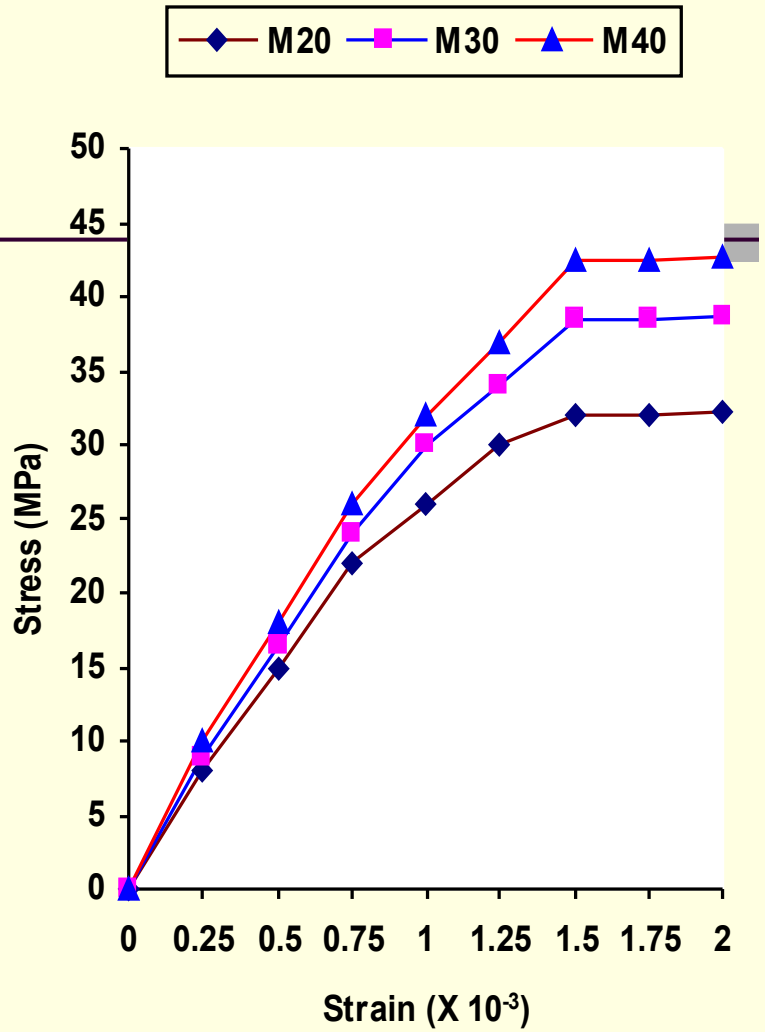
$E_c = \Delta\sigma/\Delta$, where $\Delta\sigma$ and Δ are the increase in stress and strain respectively.

$$E_c = 5000\sqrt{f_{ck}}$$ N/mm² **(OPC)**

$$E_c = 4600\sqrt{f_{ck}}$$ N/mm² **(GPC)**



Stress-Strain Curves for OPC



Stress-Strain Curves for GPC

ALKALINITY OF PORE SOLUTION

P^H Value of Geopolymer Concrete

= 11.5 – 12.3

ECONOMIC BENEFITS

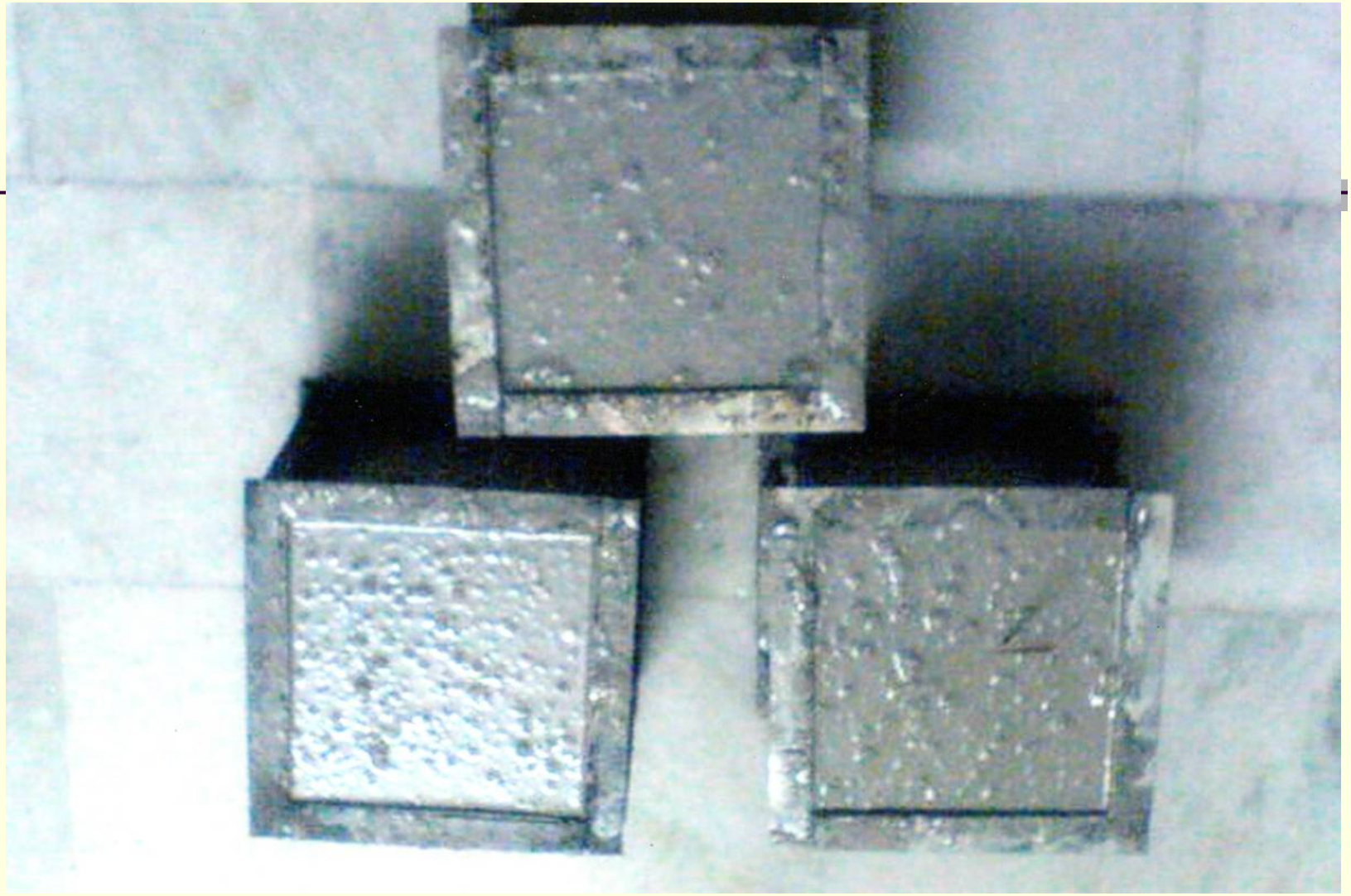
- 10 – 25 % cheaper than that of portland cement concrete
- 1 tonne fly ash utilized for 2.5 m^3 of GPC
- 1 tonne fly ash earns one carbon-credit

FLY ASH: THE MODERN POZZOLAN
IMPROVING CONCRETE PERFORMANCE
ENHANCING OUR ENVIRONMENT

GPC CUBE SPECIMEN

Fresh Geopolymer Concrete

Measurement of Slump



Geopolymer Concrete Specimens

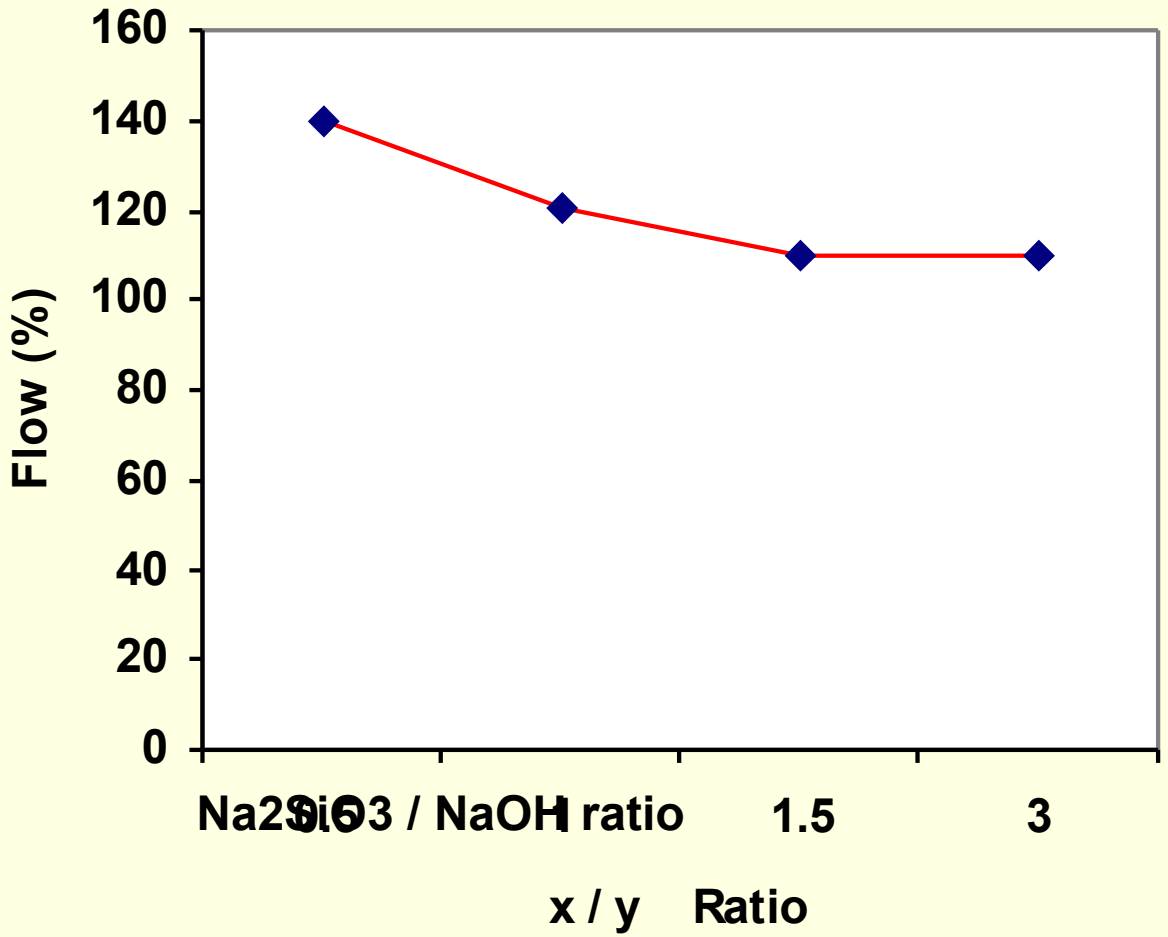
Dry (Oven) Curing

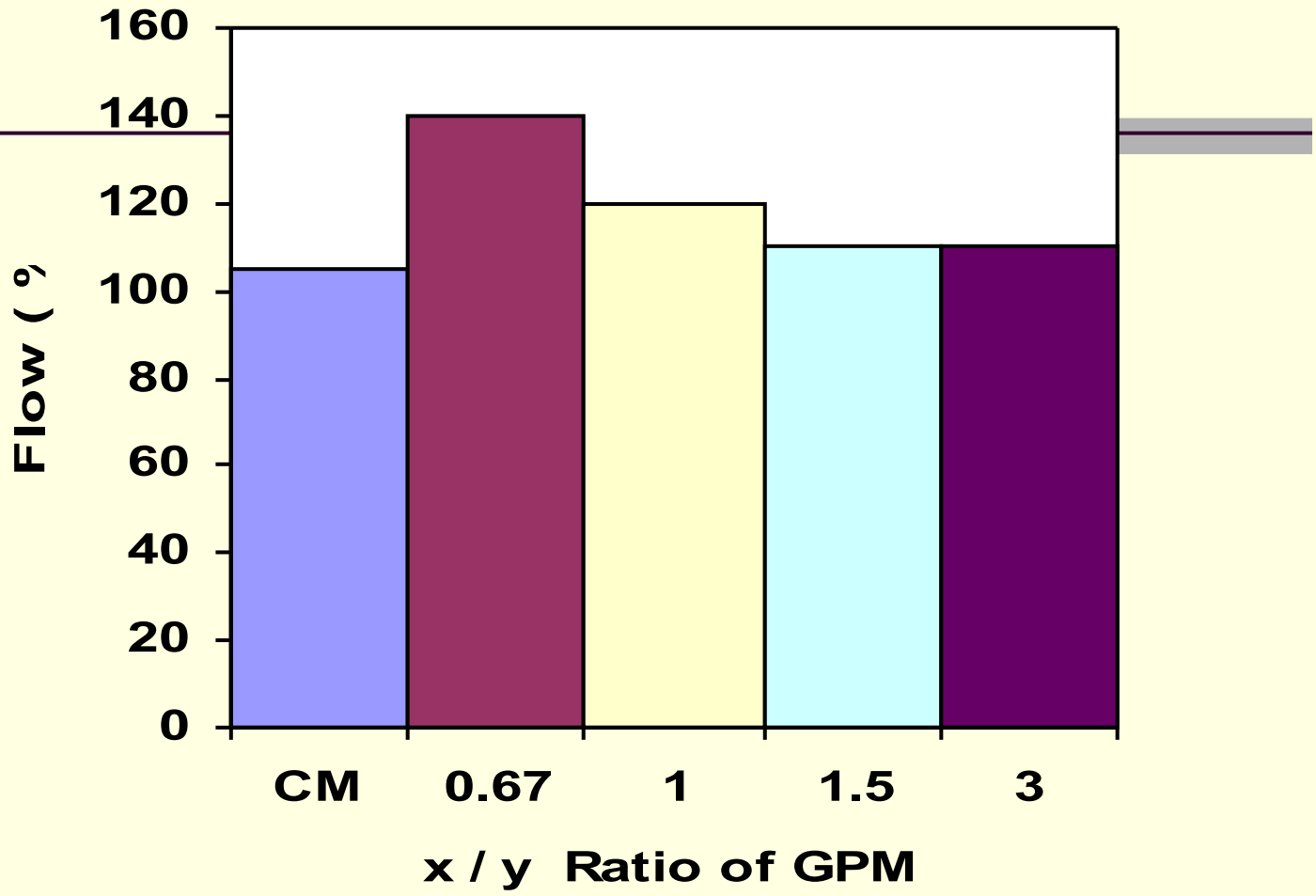
Flexural Testing of GPC mould

Compression testing equipment used to find Young's Modulus

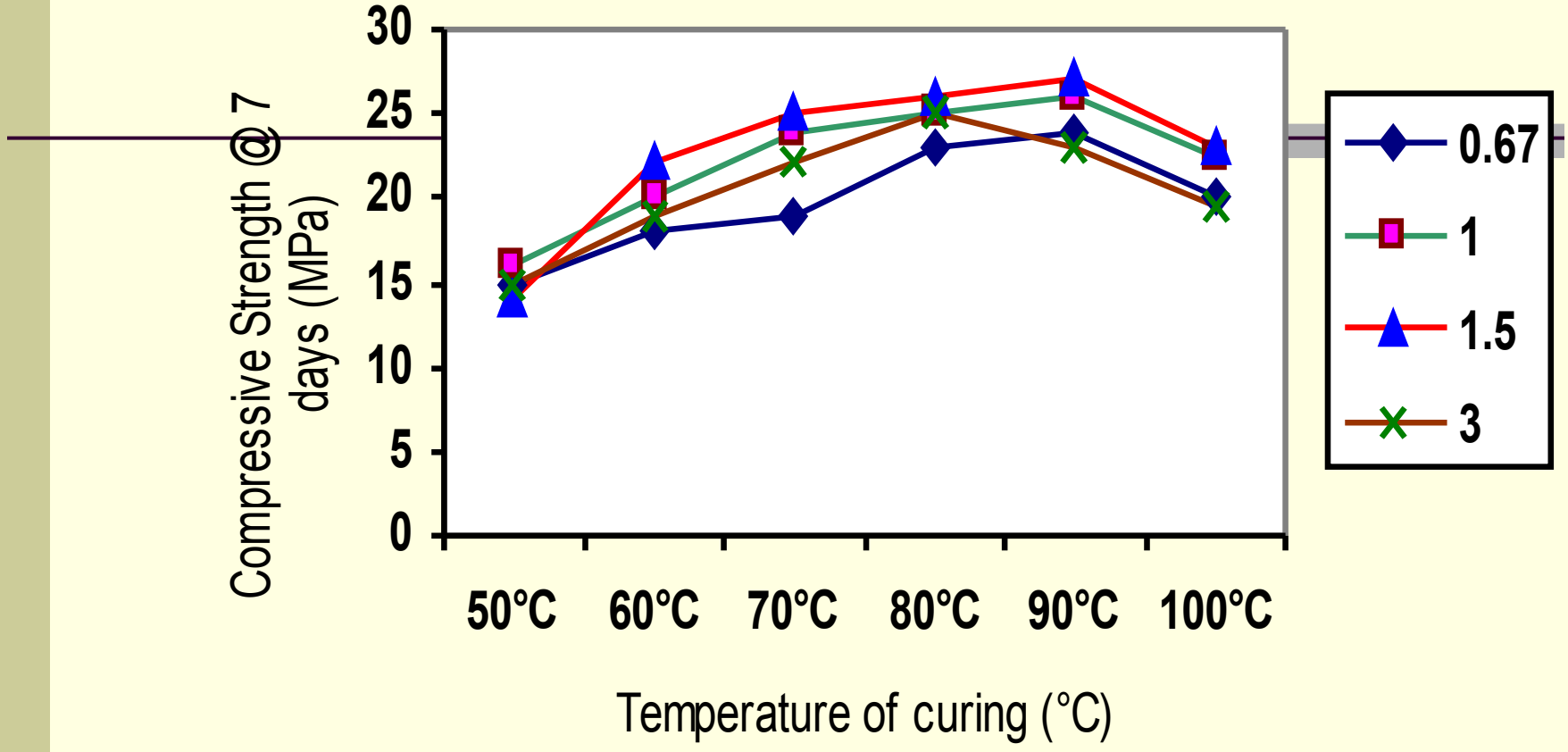
GPC Specimen after testing

GEO POLYMER MORTAR



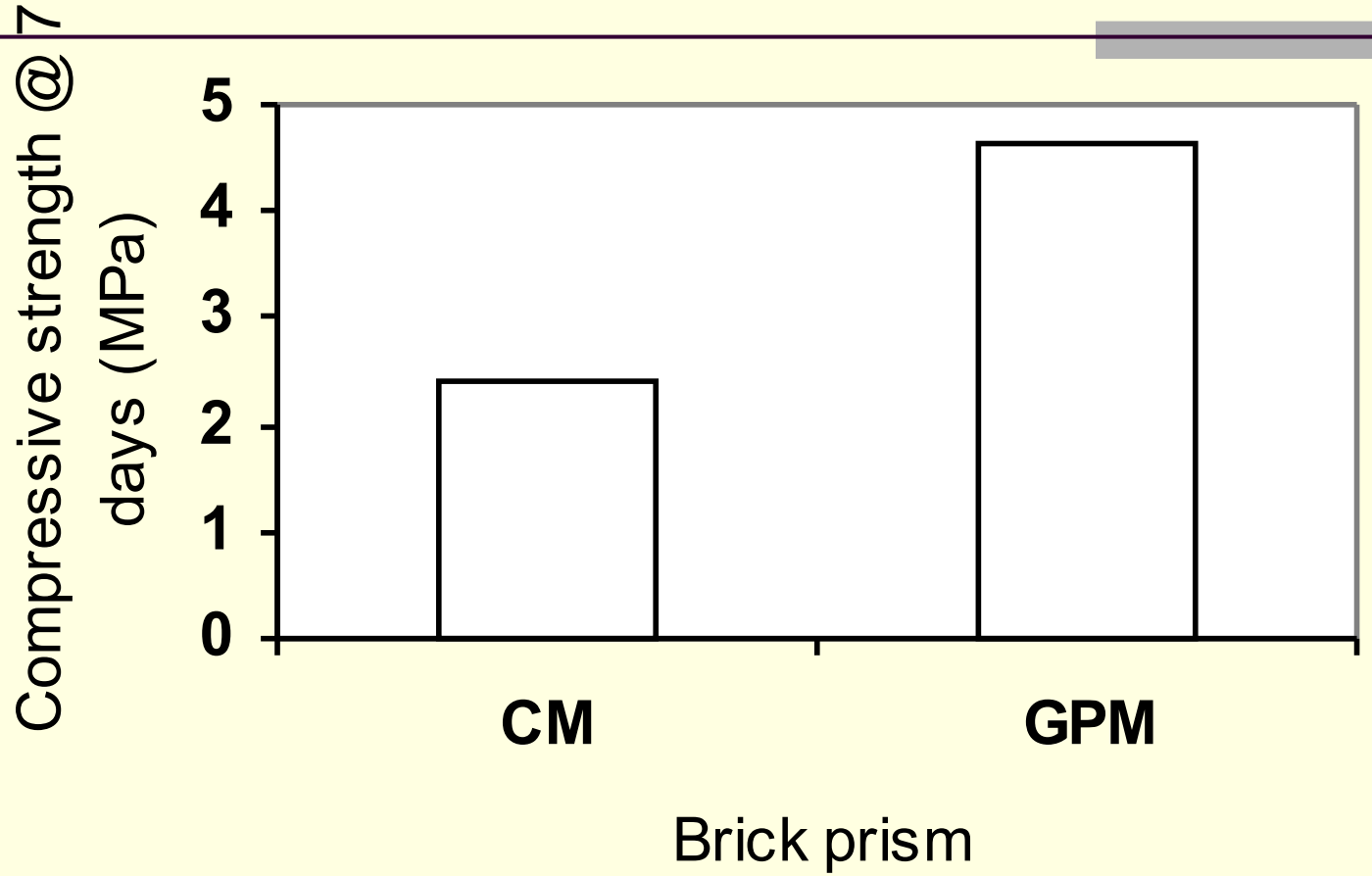


Comparison of flow between Cement mortar and Geopolymeric mortar



Variation of Strength and Temperature of curing of GPM with different Na2SiO3 / NaOH ratio

GPM Mix for Masonry works


Compressive strength @ 7 days (MPa)
5
4
3
2
1
0
CM
GPM
Brick prism

COST COMPARISON

Material		Rate	Cost of Material (Rs)				
			GPM				CM
			Mix 1	Mix 2	Mix 3	Mix 4	Mix 5
Cement		Rs. 4.80/ kg	0.00	0.00	0.00	0.00	2454.60
Fly ash		Rs. 0.20/ kg	100.60	100.60	100.60	100.60	0.00
Sand		Rs.0.40/ kg	552.80	552.80	552.80	552.80	613.60
Total for solids			653.40	653.40	653.40	653.40	3068.20
Catalytic Liquid	NaOH	Rs. 28.0/ lit	2968.00	1999.00	1332.80	666.40	0.00
	Na_2SiO_3	Rs. 11.00/ lit	701.00	701.00	701.00	701.00	0.00
Cost of GPM & CM, Rs./ M^3			4322.00	3353.00	2686.00	2020.00	3068.00

CONCLUSION

- GPC attains higher early strength than Normal concrete.
- Higher concentration of NaOH solution results in higher strength.
- 3 days curing period produces higher compressive strength.
- The Rest period is optimized to 5 days
- Density of GPC is similar to that of OPC

REFERENCES

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- Hardjito D Wallah S.E and Rangan B V , “ Research into Engineering properties of Geopolymer Concrete” International Conference Geopolymer 2002- Turn potential into profit, Melbourne, Australia, Oct-2002.
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EFFECT OF SUPERPLASTICIZER ON RHEOLOGICAL PROPERTIES OF CONCRETE

- SUPERPLASTICIZER A

(Naphthalene Formaldehyde Condensate)

- SUPERPLASTICIZER B

(Sulphonated Melamine Formaldehyde Condensate)

- SUPERPLASTICIZER C

(Aqueous De Policarboxilato)

- SUPERPLASTICIZER D

(Aqueous Solution of Ligno Sulphonate)

Properties of super plasticizer A

Composition	**Naphthalene Formaldehyde Condensate**
Specific gravity	**1.2-1.5**
Chloride content	**Nil**
Additional air content	**1% at normal dosage**
Solid content	**40%-42%**
Compatibility	**all types of cement except high alumina cement**
Operating temperature	**10˚ c to 40˚c**

Properties of super plasticizer B

Composition	Sulphonated Melamine Formaldehyde Condensate
Ph(concentrate)	~10
Boiling point/range (˚c)	>100
Flash point (closed ˚c)	none
Auto flammability(˚c)	not applicable
Explosive property(%)	not applicable
Oxidizing property	not determined
Solid content	38%-40%
Vapor pressure(kPa @ 20˚c)	2.13
Relative density(at 20˚c)	1.10(water)
Water solubility	miscible

Properties of super plasticizer C

Composition	Aqueous De Policarboxilato
Ph(concentrate)	6.5
Boiling point/range (˚c)	>100
Flash point (closed ˚c)	none
Auto flammability(˚c)	not applicable
Explosive property(%)	not applicable
Oxidizing property	not determined
Solid content	42%-45%
Vapor pressure(kPa @ 20˚c)	not determined
Relative density(at 20˚c)	1.075(water)
Water solubility	soluble

Properties of super plasticizer C

Composition	Aqueous Solution Of Ligno Sulphonate
Ph(concentrate)	4.5-5
Boiling point/range (˚c)	>100
Flash point (closed ˚c)	none
Auto flammability(˚c)	not applicable
Explosive property(%)	not applicable
Oxidizing property	not determined
Solid content	36%-38%
Vapor pressure(kPa @ 20˚c)	2.3
Relative density(at 20˚c)	1.19(water)
Water solubility	soluble

TESTS CONDUCTED

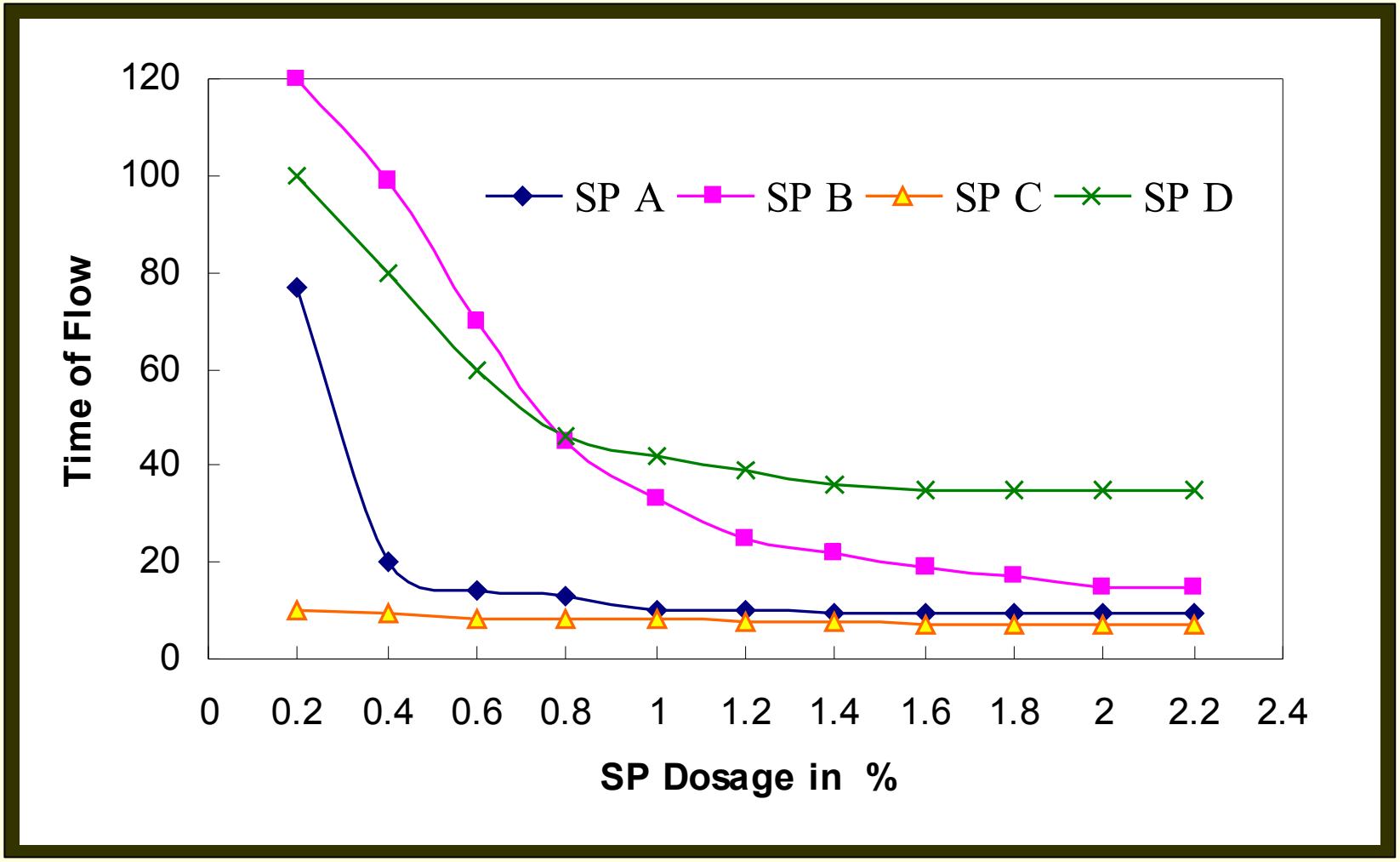
- Marsh cone test
- Mini slump test
- Flow table test

MARSH CONE TEST

Marsh cone efflux time (seconds)

S. NO.	Dosage % by weight of cement	Dosage quantity in ml	SP A	SP B	SP C	SP D
1	0.2	2	77	120	10	100
2	0.4	4	20	99	9.47	80
3	0.6	6	14	70	8.57	60
4	0.8	8	13	45	8.35	46
5	1.0	10	10	33	8	42
6	1.2	12	9.97	25	7.59	39
7	1.4	14	9.49	22	7.53	36
8	1.6	16	9.4	19	7.28	35
9	1.8	18	9.4	17	7.2	35
10	2.0	20	9.4	15	7.2	35
11	2.2	22	9.4	15	7.2	35

MARSH CONE TEST RESULTS

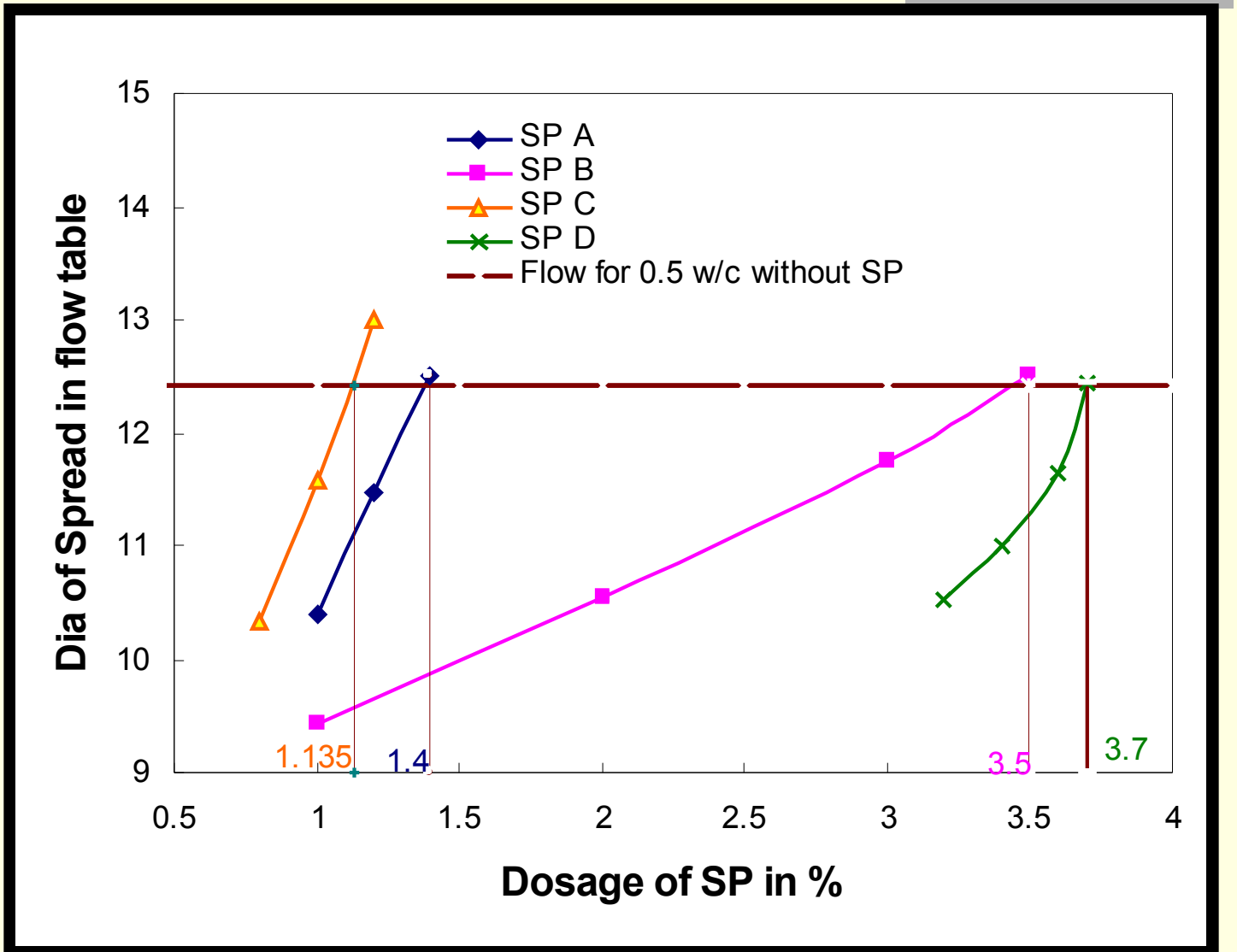


FLOW TABLE TEST

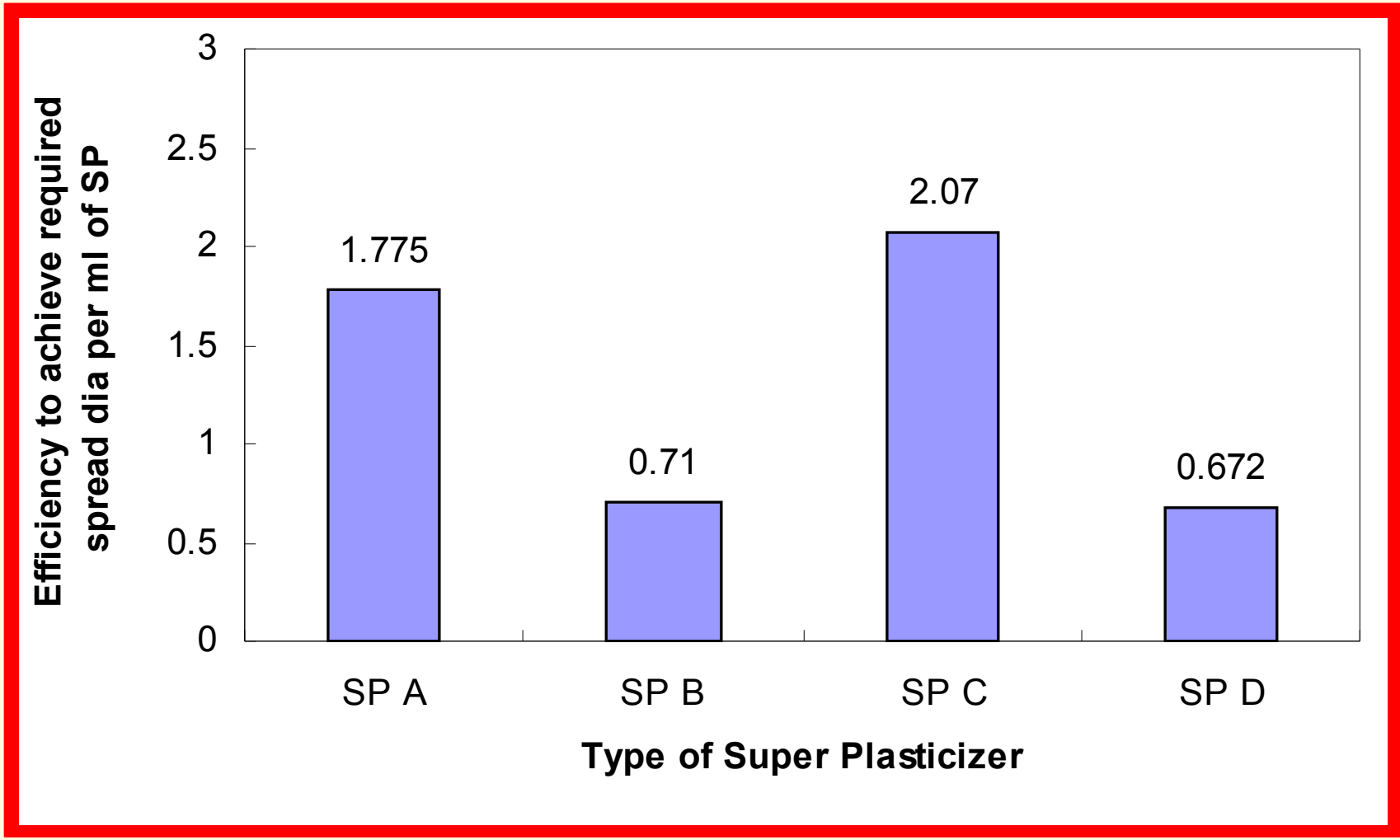
FLOW TABLE RESULTS

w/c ratio	SP Dosage in %	Average spread diameter of mortar in cm			
		A	B	C	D
0.5	0	12.425	12.425	12.425	12.425
0.4	0.8	NF	NF	10.34	NF
0.4	1.0	10.400	9.43	11.57	NF
0.4	1.2	11.475	9.43	13.00	NF
	1.4	12.500	9.43		NF
	2.0		10.55		NF
	3.0		11.75		NF
	3.2		11.75		10.53
	3.4		11.75		11.00
	3.5		12.50		11.00
	3.6				11.65
	3.7				12.45

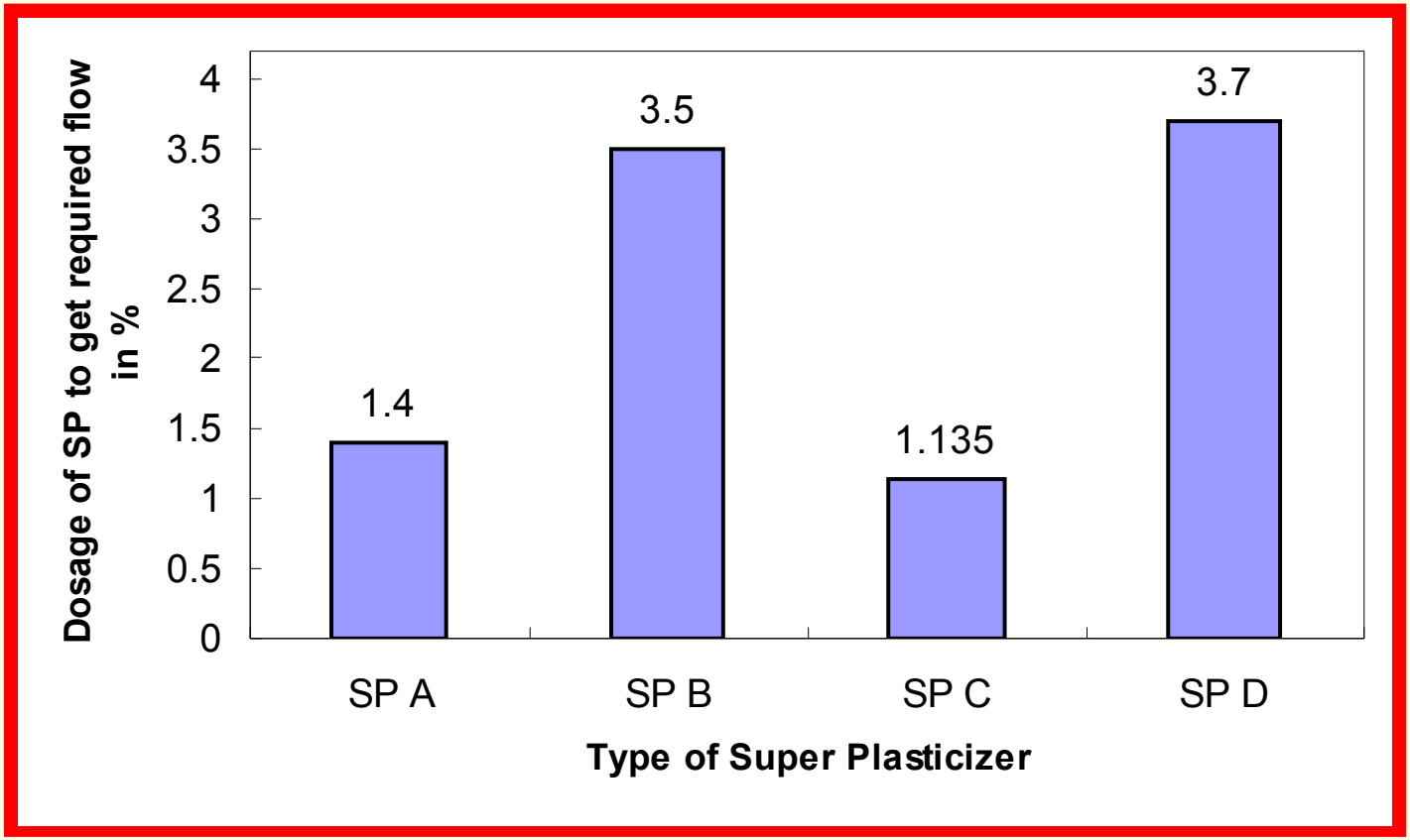
Determination of Efficiency of SP for cement mortar by flow table test



Efficiency to achieve equivalent dia of spread in mm for 1ml of SP



Comparison of efficiency of different types of SP by Flow Table Test

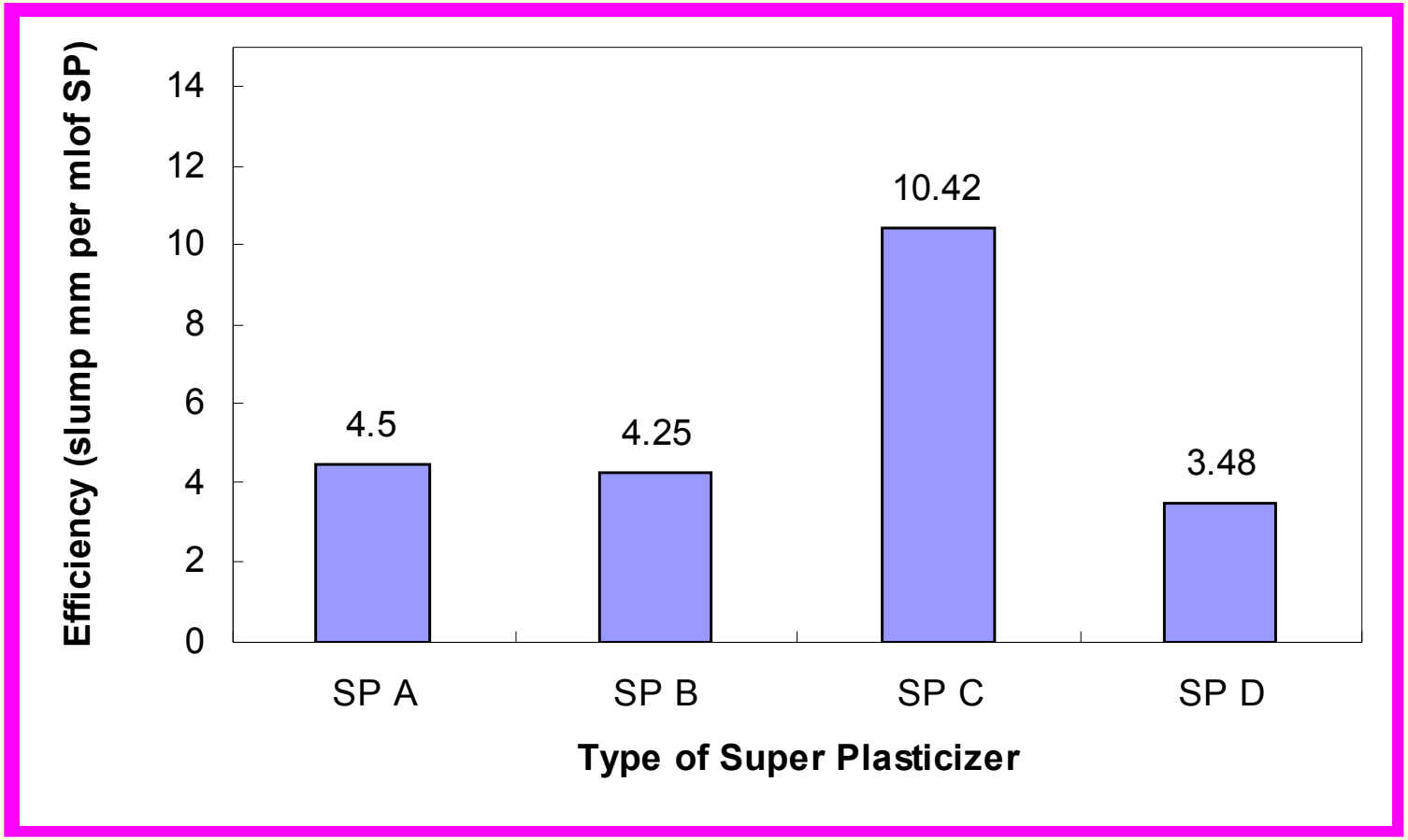


Slump Value of Different types of Super Plasticizer

FLOW RATE IN SLUMP

S. No	Type of SP	Dosage in ml	Slump mm	Time sec	Flow rate mm/sec	Efficiency mm / ml of SP
1	A	24	107	27	3.96	4.50 (II)
2	B	40	170	59	2.88	4.25 (III)
3	C	12	125	30	4.17	10.42 (I)
4	D	40	139	40.61	3.42	3.48 (IV)

Efficiency to achieve slump in mm for 1ml of SP



Compressive Strength Test Results

S.No	Type of SP	Compressive strength after 7 days curing in N/mm²	Efficiency at7 days Strength in MPa /ml of SP	Compressive strength after 28 days curing in N/mm²	Efficiency at 28 days Strength in MPa /ml of SP
1	No SP	19.77	-	28.24	-
2	A	23.33	1	34.80	1.450
3	B	21.77	0.54	32.50	0.813
4	C	27.77	2.31	41.45	3.450
5	D	nil	-	20.00	0.500

COST COMPARISON

Identification	Product	Base	Rate (Rs.)
SP A	Conplast SP 430	Sulphonated Naphthalene	90.00 / Litre
SP B	Conplast M1	Melamine	110.00 / Litre
SP C	Structuro 100	PolyCarboxilato	170.00 / Litre
SP D	Conplast P211	Ligno Sulphonate	60.00 / Litre

CONCLUSION

- Type C SP i.e., De PoliCarboxilato based SP is very compatible with cement and the efficiency with respect to workability and strength is high when compared to other types.
- Type A gives better results and its efficiency is higher than that of type B and type D super plasticizers

THANK YOU