A Technical Note on

Effect of Temperature on Quality of Fibre Reinforced Concrete

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ABSTRACT

The fire stoppings in coal mines are the walls constructed in mine galleries covering full cross-section of the openings and thus isolating the "fire area" from rest of the mine workings. The ventilation stoppings during fire or the fire stoppings themselves are usually subjected to a high temperature. It is well known fact that the thermal difference within a concrete structure results in differential volume change. When the tensile strain due to differential volume change exceeds the tensile strength of concrete, it will crack. A laboratory study of the effect of temperature on quality of the fibre reinforced concrete and plain concrete is reported in this paper.

The specimens of fibre reinforced concrete beam (350 x 100 x 50 mm) in the laboratory were subjected to heating and cooling followed by measurement of P-wave and S-wave velocities along the longer axes of the beam. It was observed that the structural damage due to heat in the concrete significantly reduced the sonic wave velocity.

1. INTRODUCTION

A research project on fibre reinforced shotcrete support in coal mines has been undertaken by the Department of Mining Engineering, Indian School of Mines, Dhanbad. Extensive field investigations followed by field trials of the steel fibre reinforced shotcrete have been carried out in underground coal mines. It has been found that even a thin layer of 30-50 mm thick shotcrete is very effective in supporting and sealing of the fractured and spalling walls and roof of galleries driven in coal (Singh, 2000).

Another application of the fibre reinforced shotcrete has been thought of in repair of damaged ventilation and fire stoppings, as well as erection of new leak-proof stoppings in mines (Singh et al., 2000). A laboratory study of the effect of temperature on quality of the fibre reinforced concrete and plain concrete is reported in this paper.

2. FIBRE REINFORCED CONCRETE

The fundamental problem with concrete is that it tends to crack due to reduction in volume during early stage of setting. This is also called shrinkage crack in concrete. Shrinkage cracks can be seen in concrete floors in houses and plaster of ventilation stoppings. This problem can be solved with fibre additives in concrete or mortar. Steel fibre and monofilament polypropylene fibre are one of the most suitable additives which increases strain capacity with critical green stage of concrete. This limits crack growth and subsequent fracture, making concrete a reliable and durable material with its optimum properties intact. In other words, the fibres provide crack control and remove the causes of weakness and thus intrinsically improve the concrete. This means traditional steel mesh can be eliminated as its only purpose is to hold fractured concrete together.

In this article, an investigation on the effectiveness of the fibres in controlling and limiting the development of the microfractures due to temperature has been reported.

3. PROPERTIES OF FIBRES

3.1 Steel fibre

- Material : Carbon steel (0.6 to 0.7 % carbon)
- Diameter : 0.55 mm
- Length : 28-30 mm
- Shape : End-hooked
- Breaking load : 2500 N/mm^2
- Numebr of fibres in one kg : 15,600

3.2 Polypropylene fibre

In this study, the monofilament polypropylene fibres from two sources were studied:

(a) Crack stop, M/s Adfil, Denmark : 12 mm long, 18μ diameter, surface treated.
(b) Staple fibre, M/s Neomer, India : 10 mm long 30μ diameter, no surface treatment.

Properties of the fibres are:

- Raw material : Polypropylene C_3H_6
- Density : 0.9 to 0.91 g/cm^3
- Softening temperature : 145-150^{o}C.

4. BASE CONCRETE MIX

4.1 Steel Fibre Reinforced Concrete

The ingredients were mixed in following proportions by weight:

- Cement: coarse aggregate (10 mm): fine aggregate: water
  1.0 **:** 2.3 **:** 1.7 **:** 0.6

4.2 Polypropylene Fibre Reinforced Concrete

The base mix was designed to attain flowable concrete having 200 mm slump. It contained maximum 4.5 mm aggregate size. The ingredients were mixed in following proportion by weight.

- Cement : Coarse aggregate : Fine aggregate : water
  1 **:** 1.5 **:** 1.5**:** 0.75

Commercial super plasticizer and water reducing agent, Zentrament Super BV was added by 1% of weight of the cement. This was the maximum dose recommended by the manufacturer. Condensed silica fume in the mix was 8% of the cement weight.

Cubes of size 150 x 150 x 150 x mm were prepared of both the mixers and cured for 28 days. The average compressive strength of cubes of both the mixers was 25 MPa.

5. ULTRASONIC TEST

The ultrasonic pulse velocity method basically involves the measurement of velocity of electronic pulses passing through concrete from a transmitting transducer to a receiving transducer. The method is based on the principle that the pulse velocity passing through concrete is primarily dependent upon the elastic properties of the material and is independent of the geometry. The method employs pulses in frequency range of 15-175 kHz generated and recorded by electronic circuit.

The ultrasonic testing can also detect internal flaws like inadequate compaction, voids, or cracks and segregation in concrete of the structure. In the region of imperfection, the ultrasonic pulse is defracted around periphery of the defect and takes more time to reach the receiving transducer. Thus, the transit time is more and the ultrasonic pulse velocity is reduced. The magnitude of reduction in the pulse velocity indicates the extent of imperfections and cracks. The Cement Research Institute of India has evolved guidelines (Table 1) for assessing the quality of concrete on the basis of sonic wave velocity in the concrete.

The instrument used in the present experiment was a 2-channel sonic viewer 170, model No. 5228, make Oyo Corporation, Tokyo, Japan for sonic wave measurement along the longer axes of the beam specimens. The frequency of P-wave transducer (serial no. 5211) and S-wave transducer (serial no. 5212) were 63 kHz and 33 kHz respectively. During measurement of the sonic wave velocity, the instrument was optimally set at the following:

Gain	Filter	Sampling range
P-wave = 100	LCF = 500 Hz	200 n sec.
S-wave = 200,	HCF = 1MHz	

Table 1- Cement Research Institute of India guidelines for assessing the quality of concrete (Gambhir, 1995).

Ultrasonic pulse velocity (P Wave) km/sec.	Quality of Concrete
> 3.5	Good
3.0 to 3.5	Medium
< 3.0	Poor

6. TEST SPECIMEN OF FIBRE REINFORCED CONCRETE

Sets of beam specimens (350 x 100 x 50 mm) of fibre reinforced concrete and plain concrete were cast in the laboratory. Each set consisted of three specimens. After 28 days curing, the specimens were dried in air before testing. Different sets of the specimens were prepared by varying the quantity of fibre and condensed silica fume. One specimen from each set was selected randomly for the testing. A description of the specimen selected for the test is given in Table 2.

7. EFFECT OF TEMPERATURE STUDY

The samples were subjected to heating and cooling cycles of 8-hour heating and 16 hours cooling for 3 days. The samples were heated at 50^{o}C, 100^{o}C, 150^{o}C, and 250^{o}C in an electric oven. The electric oven was turned off after 8 hours of heating and the samples were allowed to cool for 16 hours in the oven.

After three cycles of heating and cooling at a given temperature, P-wave and S-wave velocities in the beams were measured along longer axes of the specimens. The P-wave and S-wave velocities versus temperature are plotted in Figs. 1 to 4.

The P-wave and S-wave velocities versus the temperature plots in Figs. 1to 4 reveal that there is a general trend of increase in the sonic wave velocity up to 100^{o}C temperature, followed by decrease in the velocity at 150^{o}C and 250^{o}C. The increasing and decreasing trends of the sonic velocity with increase in temperature are similar for the steel fibre and polypropylene fibre reinforced concrete and the plain concrete.

The sonic wave velocities in two specimens B4 and A2 out of 6 specimens remained almost constant upto 100^{o}C. The increase in the sonic wave velocities up to 100^{o}C may be due to closure of already existing micro-fractures at the interface of the aggregate-cement paste. The closure of the microfracture seems to have occurred because of melting of some substance in the concrete when heated up to 100^{o}C.

Also according to the Cement Institute Research guidelines (Table 1), the quality of the concrete has been found to improve after heating upto 100^{o}C. However, these observations should be reconfirmed by other investigators also. The important properties of concrete viz. porosity, modulus of elasticity and strength of the concrete specimens after heating upto 100^{o}C should be determined in order to arrive at some conclusion.

Table 2 - Description of Fibre Reinforced Concrete Beam specimens

(A) Steel Fibre Reinforced Concrete

Specimen	Date of casting	Quantity of Steel fibre (kg/m^3)	Condensed silica fume (% wt. of cement)	Date of testing
A1	August, 2000	0	0	Nov. – Dec. 2000
A2		0	8	
A3		30	8	
A4		60	8	

(B) Polypropylene Reinforced Cement

Specimen	Date of casting	Polypropylene fibre		Condensed silica fume (% wt of cement)	Date of testing
		Quantity kg/m^3	Name		
B1	March, 2000	1	Crack stop	8	April-May, 2000
B2		2	Crack stop	8	
B3		2	Staple	8	
B4		2	Staple	8	
B5		0	-	8	
B6		0	-	8	

The P-wave and S-wave velocities both have decreased after heating of all the specimen of fibre reinforced and plain concretes upto 150^{o}C and 250^{o}C. The wave velocities must have decreased due to nucleation and propagation of micro-fracture in concrete specimens. The P-wave velocity plot in Figs. 1 & 3 indicate that initially good quality concrete is degraded to medium quality and poor quality at 150^{o}C and 250^{o}C respectively. Even the steel fibres upto 60 kg/m^3 in concrete are unable to control the nucleation and growth of the microfractures in concrete due to rise in temperature.

8. CONCLUSIONS

- Neither the steel fibres nor the polypropylene fibres are effective in checking the degradation of concrete quality at temperature beyond 100^{o}C.
- It has been observed that the quality of concrete improves by heating it upto 100^{o}C. However, this requires further confirmation by directly evaluating engineering properties of concrete such as modulus of elasticity, porosity, compressive/tensile strength, etc.

References

Gambhir, M.L. (1995). Concrete Technology, 2nd Ed. Tata McGraw Hill Publishing Company Ltd., New Delhi p. 470.

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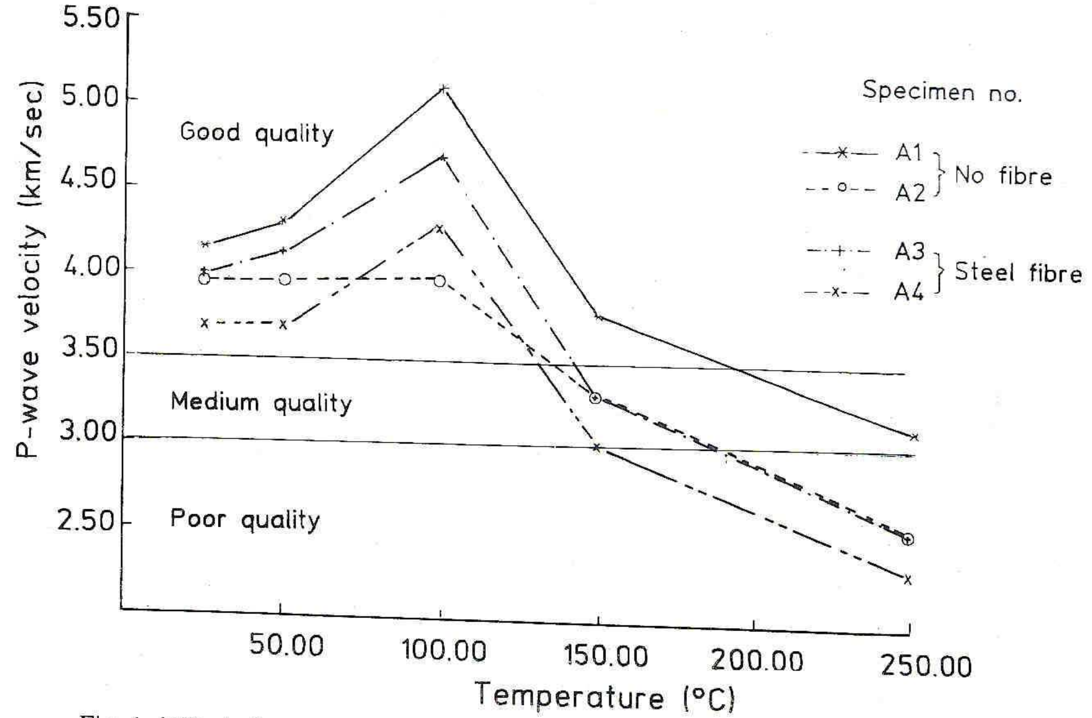

Fig. 1 - Effect of temperature on propagation velocity of P-wave through steel fibre reinforced concrete beams (Specimen Nos. A1 ... A4 refer to Table 2)

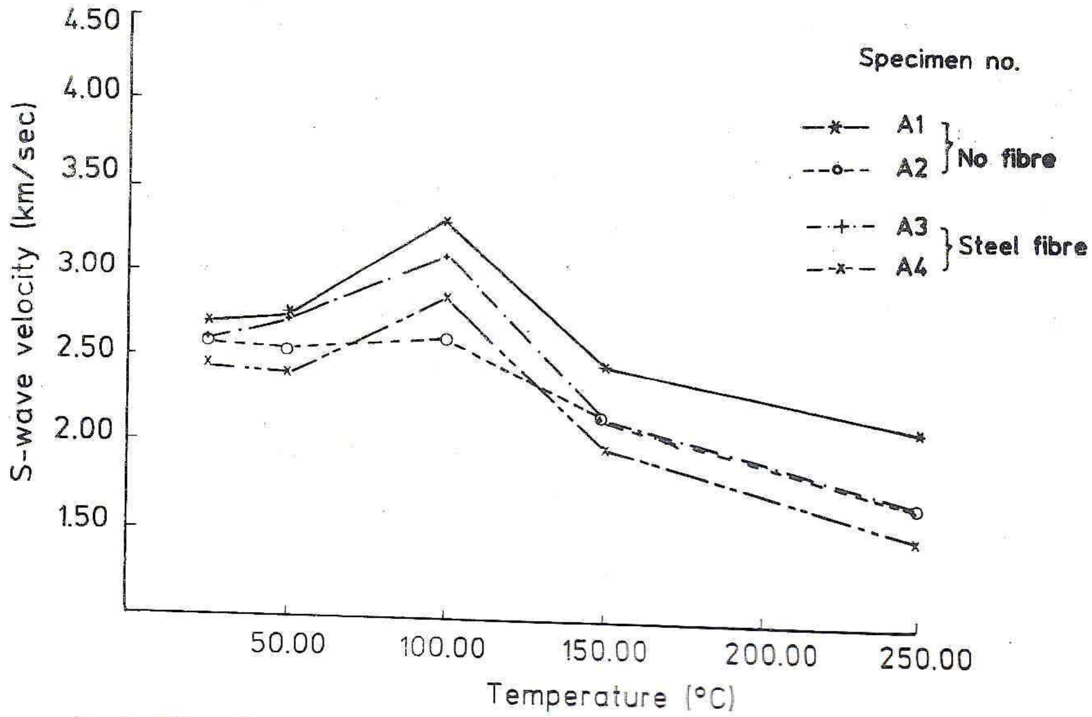

Fig. 2 - Effect of temperature on propagation velocity of S-wave through steel fibre reinforced concrete beams (Specimen Nos. A1 ... A4 refer to Table 2)

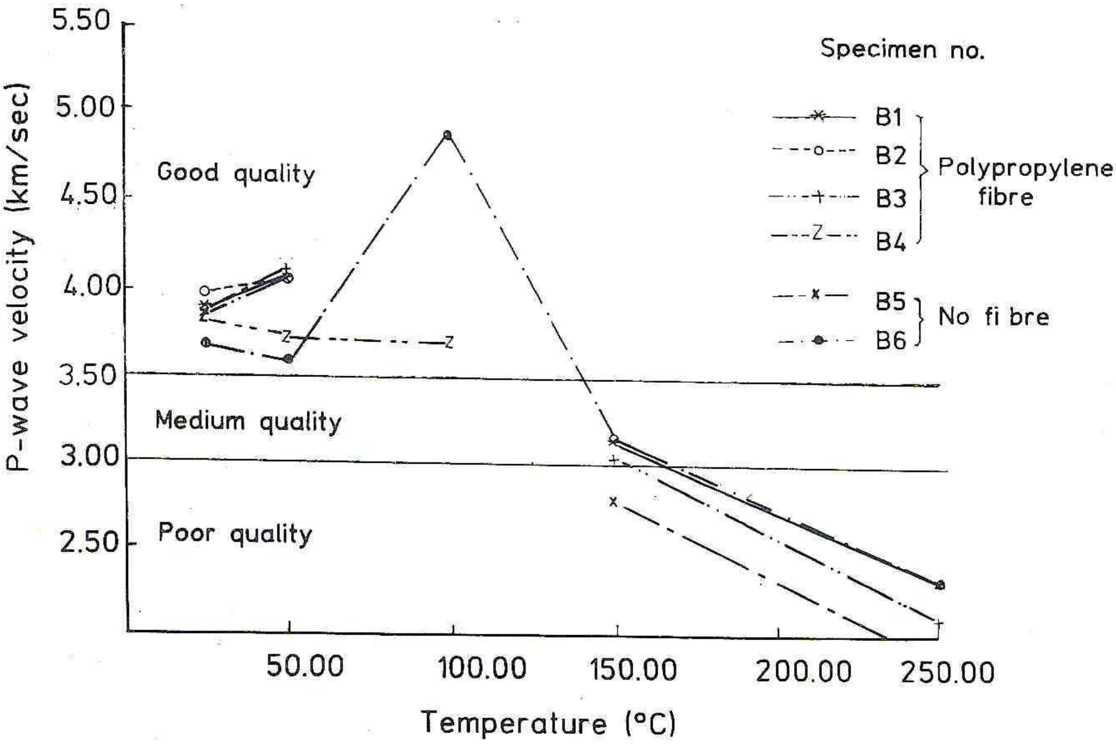

Fig. 3 - Effect of temperature on propagation velocity of P-wave through polypropylene fibre reinforced concrete beams (Specimen Nos. B1 ... B4 refer to Table 2)

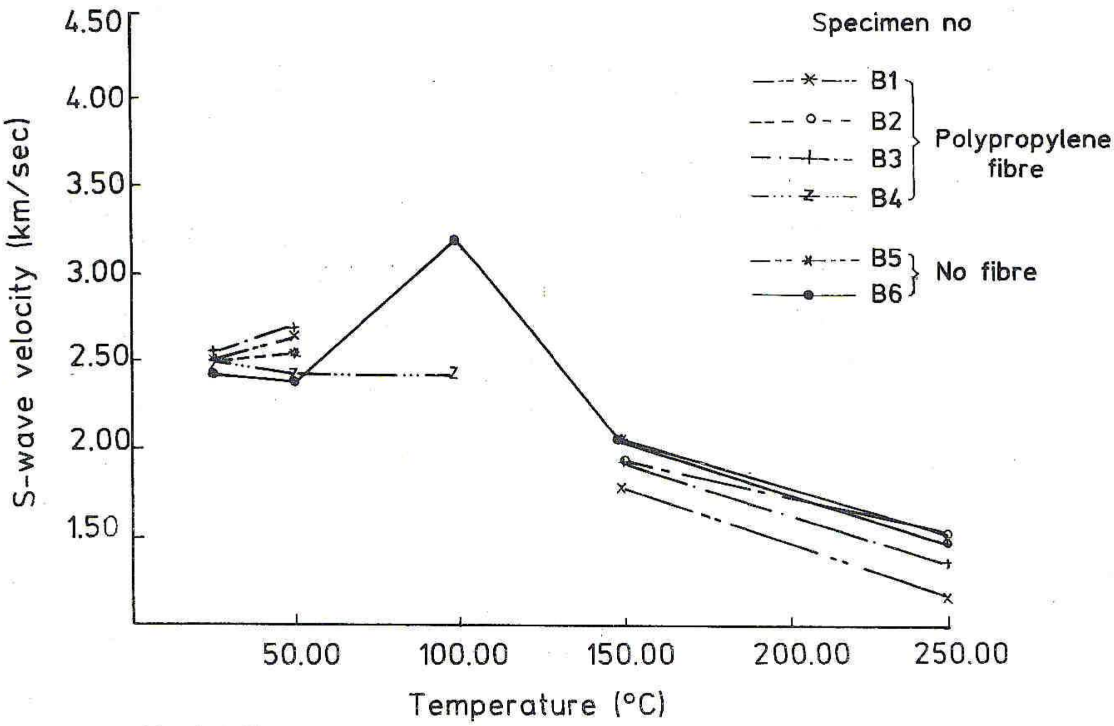

Fig. 4 - Effect of temperature on propagation velocity of S-wave through polypropylene fibre reinforced concrete beams (Specimen Nos. B1 ... B4 refer to Table 2)