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Setting Time of Granite Powder Blended Banana Fibre Reinforced High Performance Concrete

P.Murthi, K.Poongodi, R.Saravanan, R.Gobinath

Abstract: ***The investigation is intended to analyse the variations in setting time behaviour of high performance fibre reinforced concrete (HPFRC) after adding granite powder as substitute for cement. The replacement of cement by granite powder was consider at the rate of 0, 5, 10, 15 and 20%. In order to improve the performance of concrete, banana fibres are added in concrete at 0.25, 0.5, 0.75, 1.0, and 1.25% by weight of cement. High strength concrete with M50 grade was designed and investigated in this study. The investigation was carried out in two stages, the stage one was predicting the optimum level of adding banana fibre based on the strength performance and the stage two was evaluating the variations in setting time performance of hardened concrete due to addition of granite powder. The setting time of concrete was conducted using penetration resistance test as per IS: 8142-1976. The slump value of the HPFRC was maintained by 80-100 mm and the dosage of superplasticizer was modified accordingly without varying the w/c ratio. Based on the results obtained in this investigation, 1% banana fibre was taken for developing the fibre reinforced concrete without affecting the 28 days compressive strength. The substitution of granite powder beyond 15% increases the setting time significantly and also affect the strength of HPFRC. The relationship between the setting time and 28 days compressive strength was predicted.***

Keywords: Setting time, Granite powder, Banana fibre, High Performance Concrete, Compressive Strength

I. INTRODUCTION

South Indian States namely Andhra Pradesh, Karnataka, Telangana State and Tamil Nadu are the leaders in granite industry and spawned huge amount of Granite Powder (GP).

However, Telangana State is the frontrunner among the states The generated non-biodegradable GP waste are being deposited in open low level areas and also used as land filling materials which causing environmental issues [1]. The very fine dry powder can be easily inhaled causes lung diseases [2]. Due to the presence of silica in the form of GP in the atmosphere affects the growth of agricultural crops [3].

The risk of silicosis in atmospheric air leads to pollute the environment [4]. Chemically GP is rich in silica [5] and potentially possible to use as pozzolanic material in concrete and construction industry [6]. Due to the extra grinding, it is possible to improve the fineness of the GP nearer to the cement and fly-ash [7]. The research findings are showing that the GP was utilised in concrete by replacing the fine aggregate as a partial replacement material [8]. The partial replacement of sand by GP had shown the beneficial effect on controlling the plastic and drying shrinkage problems [9]. The strength properties of GP included concrete significantly improved up to 10% substitution level due to the surface nature of GP [10-11].

The literature evidences reveals that the GP was consider mostly on replacement of fine aggregate. Due to the rich in silica content of GP, the investigation was intended to consider as pozzolanic material in High Performance Concrete (HPC). In addition, the study was carried out with Banana Fibre (BF) as another composition of concrete and developing GP added Fibre Reinforced High Performance Concrete (FRHPC). The workability of fresh concrete can be controlled based on the modification of mix proportions by using superplasticizer but this process affects the setting time of concrete and leads to variations in compressive strength. With this background, the research work was intended to conduct analyse the variations in setting time on FRHPC and develop the relationship between compressive strength and setting time.

II. EXPERIMENTAL PROGRAM

A. Materials used

The market available 53 grade ordinary Portland cement as per IS: 269-2015 [14] was considered in this investigation. The specific surface area was determined as 307 m^2/g and specific gravity of the cement was also determined as 3.15. The Table 1 is shown the chemical composition of 53 grade cement. The local river sand with specific gravity of 2.67 and fineness modulus of 2.56 was used throughout the investigation. 20 mm size coarse aggregate with specific gravity of 2.67 was used this investigation. The unused banana fibres produced at our DST funded research laboratory was used in this investigation and the sample is shown in Figure 1. The physical properties of banana fibre is shown in Table 2. GP was obtained from the local granite cutting and polishing industry available in Warangal Rural District as shown Figure 2. The physical properties of GP was determined and found the specific surface area and specific gravity as 295 m^2/g and 2.56 respectively.

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* Correspondence Author
Dr.P.Murthi*, Professor, Centre for Construction Methods and Materials, Department of Civil Engineering, S R Engineering College, Warangal, India. Email: dr.murthi@srecwarangal.ac.in
Dr.K.Poongodi, Professor, Centre for Construction Methods and Materials, Department of Civil Engineering, S R Engineering College, Warangal, India. Email: poongodi@srecwarangal.ac.in
Dr.R.Saravanan, Professor, Department of Civil Engineering, Navodaya Institute of Technology, Raichur. India, Email: saravanan_gce@yahoo.co.in
Dr.R.Gobinath, Professor and Head, Department of Civil Engineering, S R Engineering College, Warangal, Email:hod_civil@srecwarangal.ac.in

The chemical composition of GP is shown in Table 1. The chemical compositions revealed that GP contains more than 72.5% SiO_2 and shows suitable for cementitious materials in concrete.

B. Experimental methods

The workability of the fresh concrete was evaluated using slump cone test as per IS: 1199-1959 [15] and shown in Figure 3. The initial and final setting time of concrete was carried out using penetration resistance apparatus based on the guidelines given in IS: 8142-1976 [16] and as shown in Figure 4. Compressive strength of 28 days cured 150 mm concrete cube was determined using 3000kN capacity motorized compression testing machine with a loading rate of 2.5 kN/s as per IS:516-1959 [17] as shown in Figure 5.

C. Mix Proportioning

M50 grade of concrete was designed for this investigation. The mix proportioning was determined as per the guidelines of IS: 10262-1982 [18]. The mix proportioning of control concrete and fibre reinforced concrete are shown in Table. 3. The banana fibre content of 0.25, 0.5, 0.75, 1.0 and 1.25% of cement was added for developing the HPFRC in stage I. The blended HPFRC mixes were designated according to the replacement of cement by GP with 5, 10, 15, 20 and 25% in stage II estigation and the mix proportioning details are shown in Table 4.

Table-I: Chemical compositions of cement and GP

Chemical compositions	Composition (%)	
	Cement	GP
SiO_2	21.92	72.5
Al_2O_3	5.71	11.61
Fe_2O_3	3.23	4.87
CaO	60.37	5.23
MgO	1.65	0.49

Table-II: Physical properties of banana fibre

Properties	Result
Diameter (μm)	150 – 300
Density (kg/m^3)	1290 – 1320
Tensile strength (MPa)	275 – 350
Young's Modulus (MPa)	12000 – 13500
Aspect ratio	35 – 50

Fig. 1 Banana Fibre

Fig.2 Granite Powder

III. RESULTS AND DISCUSSIONS

A. Effect of Banana fibre in compressive strength HPFRC

Compressive strength variations of 28 days cured banana fibre reinforced concrete is shown in Fig. 6. The results mentioned in this investigation is an average of three specimens and the average compressive strength of 28 days cured control concrete was observed as 61.05 MPa. Increasing trend of compressive strength was noticed up to 1.0% fibres in concrete.

The addition of 1.5% fibres in concrete decreases the compressive strength. Further increasing the fibre had shown the reduction in compressive strength of concrete due to the reduction of bond between aggregate and mastic portion of paste.

Based on the 28 days cured compressive strength results, the HPFRC was developed with 1% banana fibre by weight of cement without any variations of strength performance.

Chandra Mouli et al [19] and Suhas Pawar et al [20] found that the increase in compressive strength of normal strength concrete up to 4-5% of banana fibres [21]. Raphael Chacko et al [2016] found that the addition of banana fibre significantly improve the performance of flexural strength of normal strength concrete [22]

B. Effect of GP in workability of HPFRC

The workability of fresh HPFRC was measured by slump cone test. The slump value of control concrete without adding superplasticizer was found as 30 mm. The performance of the concrete in fresh state is one of the mandatory requirements in HPC and hence the superplasticizer was added up to the target slump value of 80 – 100 mm. After adding the superplasticizer, the slump value of GP blended HPFRC was determined and the results are shown in Figure 7.

Fig.3 Slump test

Fig.5 Compressive strength test

Fig.4 Penetration resistance test

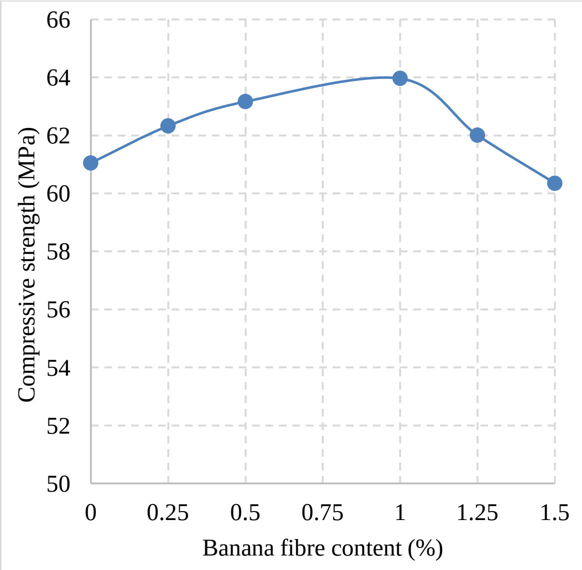

Fig.6 Compressive strength variations of HPFRC

Table-III: Mix proportioning of HPFRC

Mix ID	Cement (Kg/m^3)	Fibre		Sand (Kg/m^3)	CA (Kg/m^3)		w/c	Water (lit/m^3)
		%	Kg/m^3		20 mm	10 mm		
BF0	450.0	0	0	700	640	420	0.40	180
BF1	450.0	0.25	1.125	700	640	420	0.40	180
BF2	450.0	0.5	2.25	700	640	420	0.40	180
BF3	450.0	0.75	3.375	700	640	420	0.40	180
BF4	450.0	1.0	4.5	700	640	420	0.40	180
BF5	450.0	1.25	5.625	700	640	420	0.40	180

Table-IV: Mix proportioning of GP added HPFRC

Mix ID	Cement		GP		Banana fibre (kg/m^3)	Water (lit/m^3)	Superplastizer (lit/m^3)
	%	kg/m^3	%	kg/m^3			
GP0	100	450.0	0	0	4.5	180	3.9
GP5	95	427.5	5	22.5	4.5	180	3.9
GP10	90	405.0	10	45.0	4.5	180	3.9
GP15	85	382.5	15	67.5	4.5	180	3.9
GP20	80	360.0	20	90.0	4.5	180	3.9
GP25	75	337.5	25	112.5	4.5	180	3.9

C. Effect of GP in initial and final setting time of HPFRC

The penetration resistance test results for 0% and 10% GP is depicted in Figure 8. The force necessary for the penetration and time inserting from the time water is added to the cement is noted. The recorded force divided by the bearing area of the needle gives the penetration resistance. This is plotted as a graph using the penetration resistance equal 3.5 MPa, the point of intersection with the X-axis, which gives the initial setting time and the penetration resistance of 27.6 MPa shows the final setting time of concrete. The initial and final setting time of mixes considered in this investigation based on the replacement level of GP are shown in Figure 6. The initial and final setting time of HPFRC without the replacement of cement by GP was determined as 68 and 158 minutes respectively as shown in Figure 9.

The substitution of GP in HPFRC was significantly increases the setting time up to 10% replacement of cement by GP. The significant increase in both initial and final setting time of HPFRC was observed after the addition of more than 15% GP in the concrete which shows that the more absorption behavior of GP reduces the hydration process which causes the rate of setting time in concrete mass. The addition of mineral admixtures in concrete increases the setting time of concrete [23-27]. The effect of mineral admixtures on setting time of high strength concrete was examined by Sunil Kumar and Kameshwara Rao [28] and found that the substitution of mineral admixtures retarding the setting time of concrete. The relationship between initial and final setting time was developed in order to validity of the results which shows a linear variation with high correlation co-efficient as shown in Figure 10.

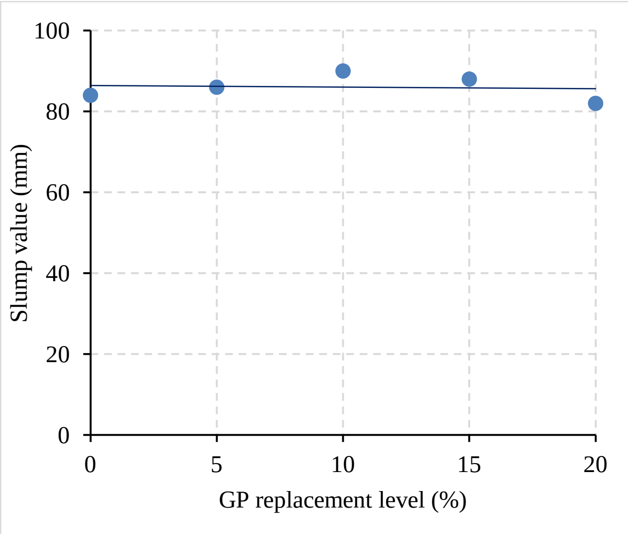

Fig.7 Slump values vs. GP replacement with SP

D. Effect of setting time on compressive strength of HPFRC

The variation of compressive strength of 7, 28 and 90 days cured cube specimens after the addition of GP in HFRC depicted in Figure 11. The results obtained from the compressive strength had shown that insignificant decreases the compressive strength linearly up to 10-15% the substitution of GP and non-linear significant variations were noticed beyond 15% substitution of GP. The effects of initial and final setting time of HPFRC due to the substitution of GP in compressive strength are shown in Figure 12 and 13.

The correlation of initial setting time and the compressive strength was predicted as $f_c = 143.4\ (IST)^{-0.194}$ with higher correlation coefficient of 0.9964 and the relationship between final setting time with compressive strength was found as $f_c = 198.91\ (FST)^{-0.227}$ with correlation coefficient of 0.9876. Brooks et al and Aggoun et al developed empirical model for finding the final setting time based on the initial setting time and replacement of cement by Bagasse ash and proved with validation [29-30].

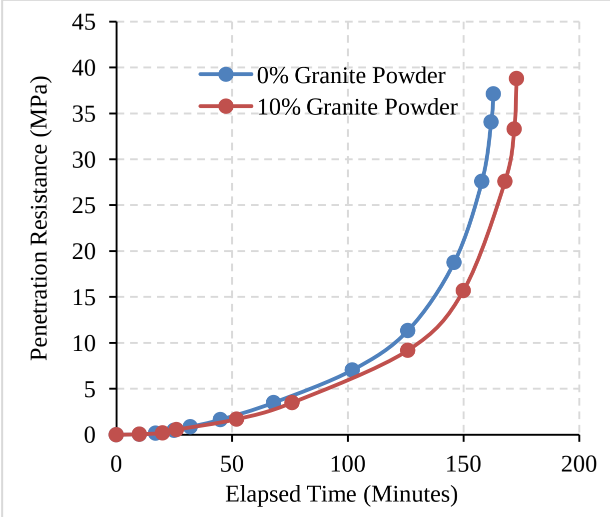

Fig.8 Setting time of HPFRC

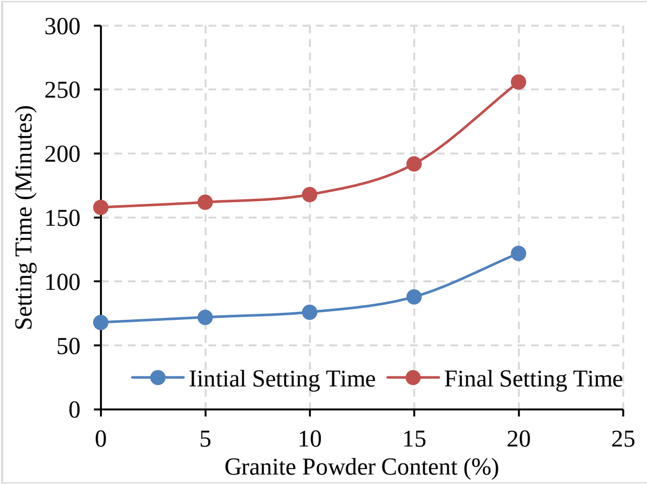

Fig.9 Initial and Final setting time of HPFRC

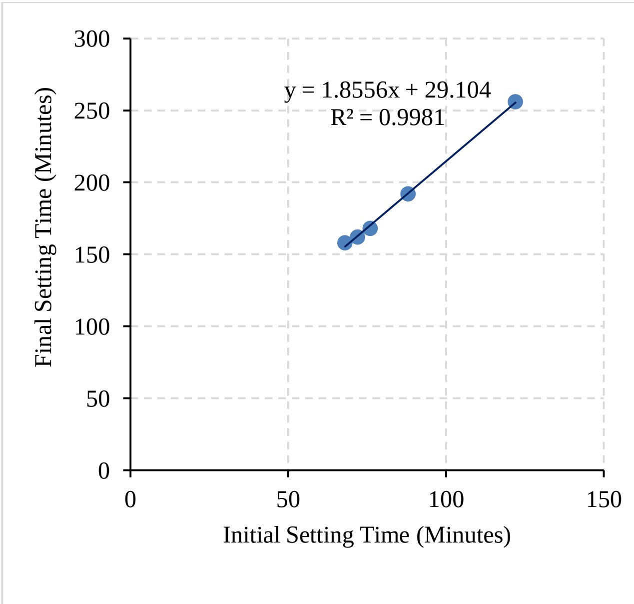

Fig.10 Initial setting time vs. Final setting time of HPFRC

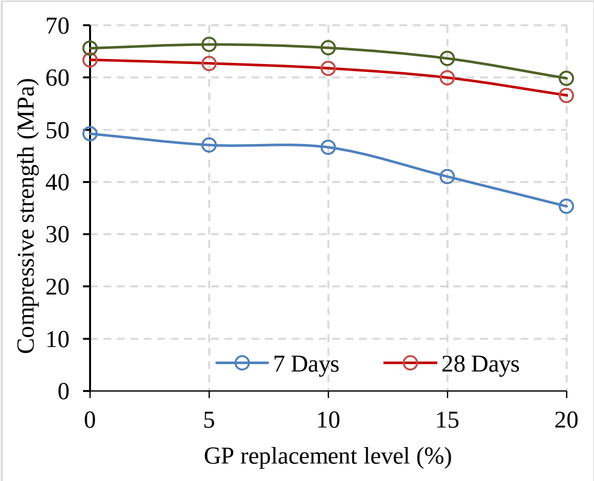

Fig.11 Compressive strength vs. GP replacement

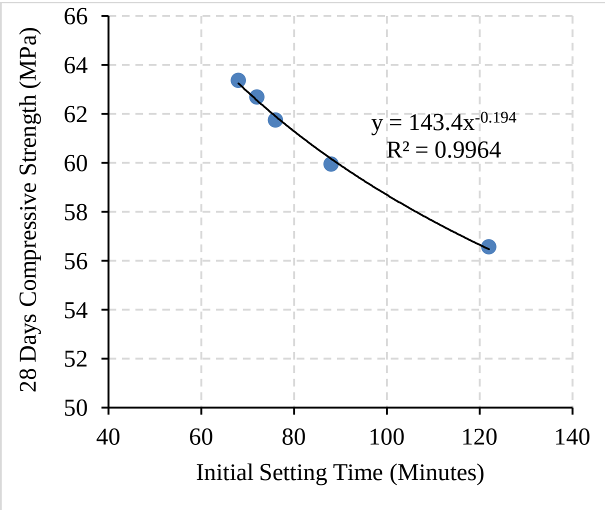

Fig.12 Compressive strength vs. Initial setting time

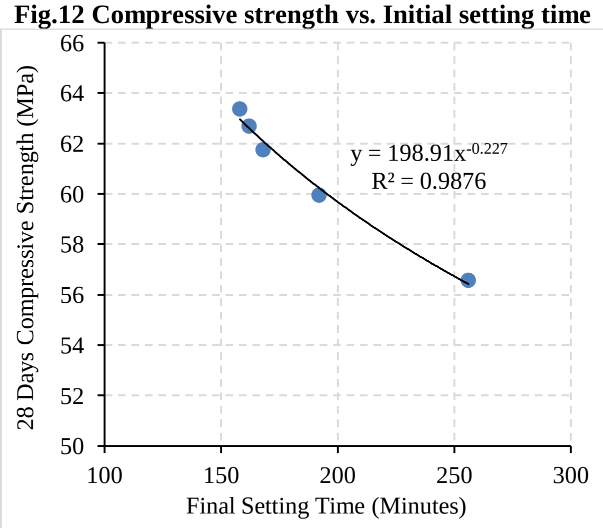

Fig.13 Compressive strength vs. Final setting time

IV. CONCLUSIONS

The following conclusions were arrived from this investigation:

1. The substitution level of GP is optimized as 18% replacement of cement for developing binary blended concrete and considered as control concrete for further investigation.
2. The addition fibre in concrete causing reduction of workability and it is due to reduction of mortar fraction in fresh concrete since the mortar is coated with fibre content. The reduction of mortar for reaction is constantly increases by increasing the fibre content fibre present in concrete.
3. Increasing trend of compressive strength was noticed up to 0.5 % fibres in concrete. Further increasing the fibre had shown the reduction in compressive strength of concrete due to the portion of paste form was coated with fibre causes the reduction of paste in concrete. From the investigation, it was determined that the optimum substitution of fibre was found as 0.5% by weight of concrete.
4. The tensile strength were determined by both splitting tensile strength and flexural strength. The results was noticed in decreasing order due to the presence of more fibre content and it causes the reduction of bond between paste form and aggregate form in the concrete mass.
5. The reduction of sorptivity was observed by addition of fibres up to 0.5% and further addition of fibre was developed negative impact in sorptivity and the capillary suction of water was starts slightly increased. The presence of more fibre content developed more discontinuous cracks and voids in the concrete and it causes to increase the sorptivity of concrete.

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AUTHORS PROFILE

Dr.P.Murthi, working as Professor in Department of Civil Engineering at S R Engineering College, Warangal, Telangana State. He has published more than 50 research papers in indexed journals and conferences. He has 32 years of teaching experience including 12 years of research experience. He guided 5 Ph.Ds and currently 1 Ph.D scholar pursuing Ph.D under his supervision. His area of interest in special structural concrete.

Dr.K.Poongodi, working as Professor in Department of Civil Engineering at S R Engineering College, Warangal, Telangana State. She has published more than 10 research papers in indexed journals and conferences. She has 14 years of teaching experience including 6 years research experience. Her area of interest in Self compacting concrete and Agriculture solid waste as aggregate in concrete and its durability.

Dr.R.Saravanan, working as Professor and Head, Department of Civil Engineering at Navodaya Institute of Technology, Raichur, Karnataka. He has published more than 5 research papers in indexed journals and conferences. He has 10 years of teaching experience including 5 years industrial experience. His area of interest in soil stability and application of additives for improving the soil properties.

Dr.R.Gobinath, is presently working as Professor in the department of Civil Engineering of S R Engineering College, Warangal, Telangana, India. He is an active researcher in the field of building materials, geo-materials, sustainable building materials and environmental geo-technology. He has more than 103 papers to his credit and is actively serving in the editorial board of various journals of Springer, IGI global and also serving as reviewer for numerous journals in the field of Civil engineering and material science.