Journal of Civil Engineering and Construction Technology Vol. 2(10), pp. 218-235, October 2011
Available online at http://www.academicjournals.org/JCECT
ISSN 2141-2634 ©2011 Academic Journals

Full Length Research Paper

Characteristic studies on the mechanical properties of quarry dust addition in conventional concrete

A. Sivakumar* and Prakash M.

Department of civil engineering, Vellore Institute of Technology (VIT) University, India.

Accepted 1 September, 2011

Currently India has taken a major initiative on developing the infrastructures such as express highways, power projects and industrial structures etc., to meet the requirements of globalization, in the construction of buildings and other structures. Concrete plays the key role and a large quantum of concrete is being utilized in every construction practices. River sand, which is one of the constituents used in the production of conventional concrete, has become very expensive and also becoming scarce due to depletion of river bed. Quarry dust is a waste obtained during quarrying process. It has very recently gained good attention to be used as an effective filler material instead of fine aggregate. In the present study, the hardened and durable properties of concrete using quarry dust were investigated. Also, the use of quarry dust as the fine aggregate decreases the cost of concrete production in terms of the complete replacement for natural river sand. This paper reports the experimental study which investigated the influence of 100% replacement of sand with quarry dust. Initially cement mortar cube was studied with various proportions of quarry dust (CM 1:3, CM 1:2, and CM 1:1). The experimental results showed that the addition of quarry dust for a fine to coarse aggregate ratio of 0.6 was found to enhance the compressive properties as well as elastic modulus.

Key words: Concrete, quarry dust, fillers, elastic modulus, compressive strength.

INTRODUCTION

In the recent past good attempts have been made for the successful utilization of various industrial by products (such as flyash, silica fume, rice husk ash, foundry waste) to save environmental pollution. In addition to this, an alternative source for the potential replacement of natural aggregates in concrete has gained good attention. As a result reasonable studies have been conducted to find the suitability of granite quarry dust in conventional concrete.

However, recycled concrete aggregate, fly ash, blast furnace slag, as well as several types of manufactured aggregates have been studied by many researchers, Zain et al. (2000); Neville (2002); Gambhir (1995). Quarry dust, a by-product from the crushing process during quarrying activities is one of those materials that have recently gained attentions to be used as concreting aggregates, especially as fine aggregates. Quarry dust have been used for different activities in the construction industry, such as road construction, and manufacture of building materials, such as lightweight aggregates, bricks, tiles and autoclave blocks.

Researches have been conducted in different parts of the world, to study the effects of incorporation of quarry dust into concrete. Galetakis and Raka (2004) studied the influence of varying replacement proportion of sand with quarry dust (20, 30 and 40%) on the properties of concrete in both fresh and hardened state (Nevillie, 2002).

Saifuddin et al. (2001) investigated the influence of partial replacement of sand with quarry dust and cement with mineral admixtures on the compressive strength of concrete (Gambhir, 1995), whereas Celik and Marar investigated the influence of partial replacement of fine aggregate with crushed stone dust at varying percent-tages in the properties of fresh and hardened concrete (Safiuddin et al., 2001; Celik and Marar, 1996). The present study is intended to study the effects of quarry dust addition in conventional concrete and to assess the rate of compressive strength development for different quarry dust to coarse aggregate ratio, (Goble (1999); De Larrard and Belloc, 1997).

*Corresponding author. E-mail: sivakumara@vit.ac.in. Tel: 9840844923, 0416-2202256.

Table 1. Physical properties of cement.

S/N	Properties	Results obtained
1.	Specific gravity	3.37
2.	Initial Setting Time (minutes)	33.00
3.	Final Setting Time (minutes)	480.00
4.	Standard Consistency (%)	32%

METHODOLOGY

Cement

In the present study an ordinary Portland cement (OPC 53 grade) was used. The physical properties of the cement tested according to Indian standards procedure confirms to the requirements of IS 12269 and the physical properties are given in Table 1.

Fine aggregate

The river sand conforming to zone II as per IS-383-1987 was used for making reference concrete and its specific gravity was found to be 2.3. The loose and compacted bulk density values of sand were 1455 and 1726 kg/m^3 respectively.

Quarry dust

The basic tests on quarry dust were conducted as per IS-383-1987 and its specific gravity was around 1.95. Wet sieving of quarry dust through a 90 micron sieve was found to be 78% and the corresponding bulking value of quarry dust was 34.13%.

Coarse aggregate

Crushed granite coarse aggregate conforming to IS 383-1987 of size 12 mm and down having a specific gravity of 2.6 was used. The loose and compacted bulk density values of coarse aggregate were 1483 and 1680 kg/m^3**,** respectively, for different grade of concrete.

Chemical admixture

Workability of concrete mixtures was tested using slump cone test to obtain a target slump of 75 -90 mm. In the present study, a naphthalene based super plasticizer was used at an optimum dosage, not exceeding 1.0% by weight of cement.

Water

Water is an important ingredient of concrete as it initiates the chemical reaction with cement, and the mix water was completely free from chlorides and sulfates. Ordinary potable water was used throughout the investigation as well as for curing concrete specimens.

Concrete mixture proportions

Concrete consists of a two phase material, namely mortar and aggregate phases. Hence in the present study the two phases were studied separately. Three types of mortar mixtures were taken in the ratio of 1:3, 1:2 and 1:1. The cement mortar cubes containing 100% replacement of sand with quarry dust were compared with conventional mortar cube prepared with natural river sand. Concretes, namely M1, M2 and M3, were prepared with the w/c ratio of 0.32. For all concrete mixtures, the fine to coarse aggregate ratio varied at 0.6, 0.7 and 0.8. The performance characteristics of all quarry dust concretes were compared with reference concrete containing without quarry dust. Three different binder contents were chosen at 300, 350 and 400 kg/m^3. The dosages of the super-plasticizers were kept constant by monitoring the desired flowability in trial mixtures. The details of the mixture proportions were presented in Table 2.

Mixing details

A rotating pan mixer (capacity 0.05 m^3) was used for mixing the constituent material. Fresh concrete was then casted in a 100 mm cube mould, 150 × 300 mm and 100 × 200 mm cylindrical mould. Immediately after demoulding, the specimens were kept in the curing tank at 25 ± 3°C. The compressive strength of the concrete specimens was determined in accordance to IS: 516-1959 (Table 3). The experimental test results presented are the average of five specimens.

RESULTS AND DISCUSSION

Compressive strength on mortar cube

The 7.05 × 7.05 × 7.05 mm mortar cubes were tested to determine the compressive strength properties of different specimens. The compressive strength was obtained as per IS: 516-1959. The 3, 7 and 28 days compressive strength of mortar cube were shown in Figure 1. The 28 days compressive strength of 100% replacement of sand with quarry dust of mortar cube (CM 1:1) was 11.8% higher than the controlled cement mortar cube. The 3, 7 and 28 days compressive strength of cement mortar had shown a decreasing trend compared to the reference concrete.

Effect of quarry dust on compressive strength of concrete

The 100 mm size concrete cubes were used as test specimens to determine the compressive strength. The test results of the cubes are compiled in Figures 2 to 7. Compressive strength was obtained as per IS: 516-1959. The compressive strength of concrete cube (100% replacement of sand with quarry dust) and natural sand were compared. The compressive strength of concrete cube containing 100% replacement of sand with quarry dust the value ranges between 21.3 to 33.63 MPa. For a binder content of 300 kg/m^3. The maximum compressive strength of concrete cube containing 100% replacement of sand with quarry dust was found to be 33.63 MPa at 56 days for a fine to coarse aggregate ratio of 0.7. The reference compressive strength of concrete cube ranged between 18.70 to 42.10 MPa for different fine to coarse

Table 2. Concrete mixture proportions.

Mix ID	Cement (kg/m³)	F/C (kg/m³)	Fine Aggregate (kg/m³)	Coarse aggregate (kg/m³)	Water (kg/m³)	Super plasticizer dosage (kg/m³)	w/c
		0.6	787.50	1312.50	420.00		
Mix 1	300	0.7	864.71	1235.29	395.29	2.40	0.32
		0.8	933.30	1166.67	373.33		
		0.6	768.75	1281.25	410.00		
Mix 2	350	0.7	844.12	1205.88	385.88	2.80	0.32
		0.8	911.00	1138.89	364.44		
		0.6	750.00	1250.00	400.00		
Mix 3	400	0.7	823.50	1176.47	376.47	3.20	0.32
		0.8	889.00	1111.11	355.55		

Table 3. Compressive strength results of various concrete mixtures.

Mix ID	Cement (kg/m³)	F/C (kg/m³)	Compressive strength of concrete (MPa)					
			without quarry dust			with quarry dust		
			7 days	28 days	56 days	7 days	28 days	56 days
		0.6	23.05	40.20	42.10	21.3	28.2	29.9
Mix 1	300	0.7	18.70	25.63	29.10	23.53	25.43	33.63
		0.8	33.36	35.60	37.20	22.33	25.33	26.10
		0.6	36.56	38.50	39.60	32.90	36.40	36.46
Mix 2	350	0.7	34.99	36.33	38.80	23.76	29.27	30.40
		0.8	31.50	36.70	38.10	32.76	34.50	38.10
		0.6	24.90	26.90	31.10	13.80	21.13	37.66
Mix 3	400	0.7	21.40	22.50	24.50	18.80	27.30	29.60
		0.8	31.10	24.50	36.00	22.90	23.93	31.00

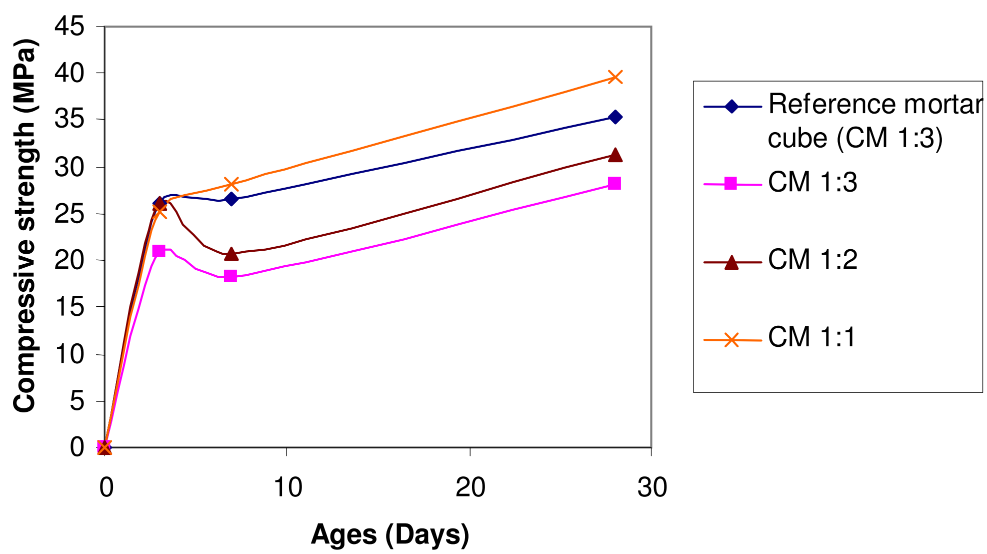

Figure 1. Compressive strength of mortar cube.

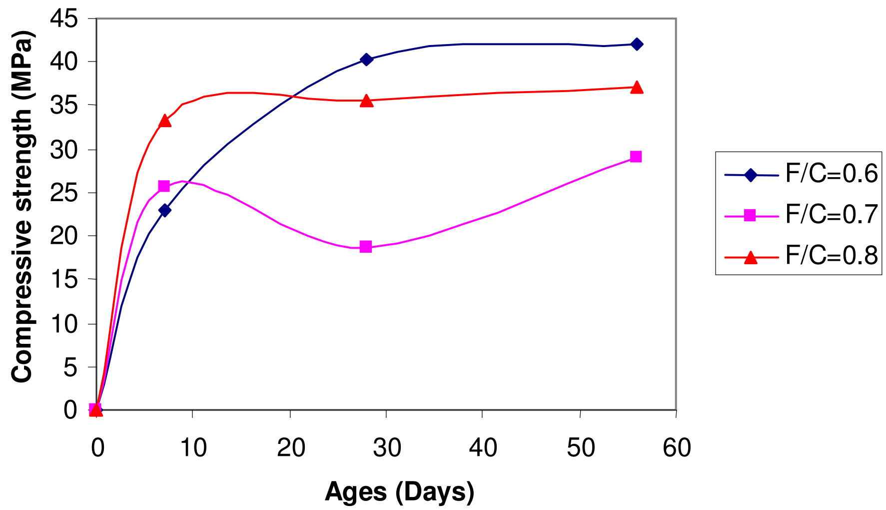

Figure 2. Reference compressive strength of concrete at 300 Kg/m^3

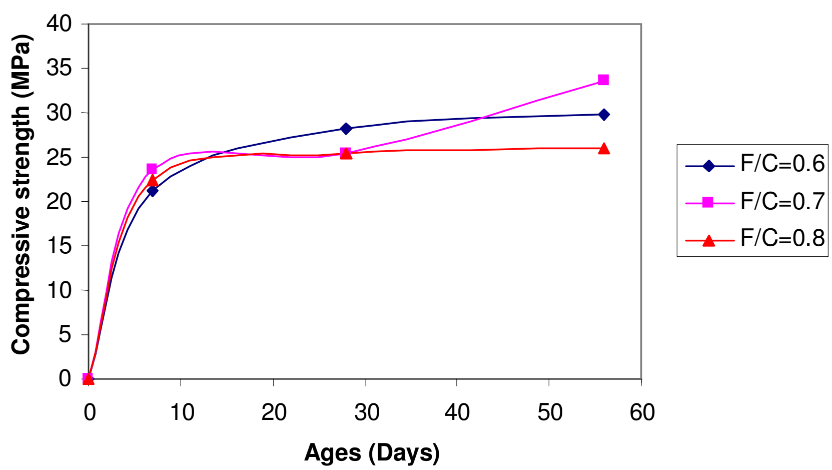

Figure 3. Effect of quarry fines on compressive strength of concrete at 300 Kg/m^3.

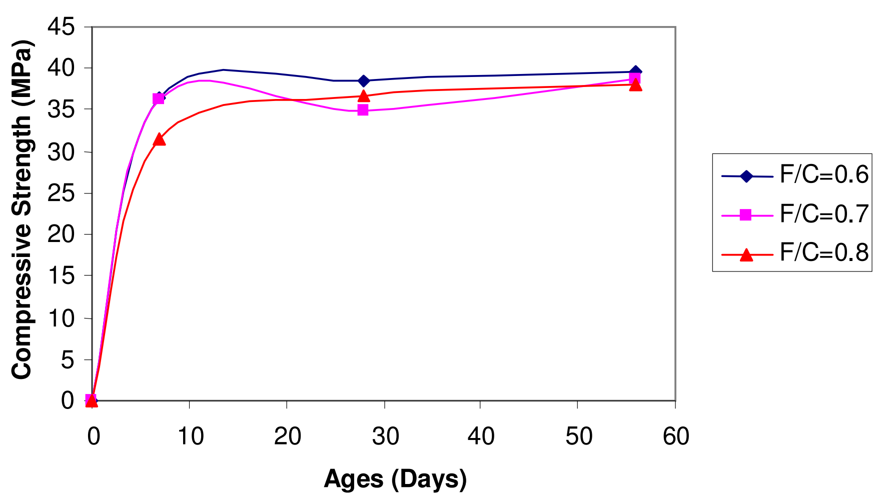

Figure 4. Reference compressive strength of concrete at 350 kg/m^3.

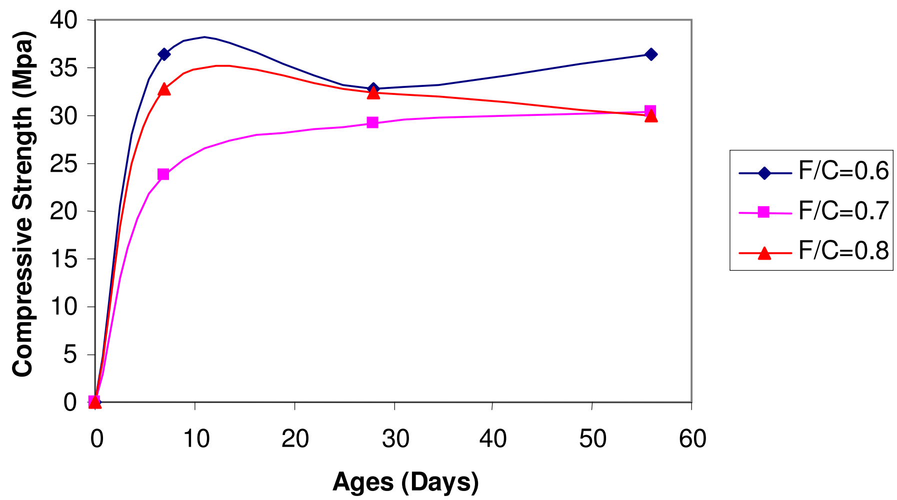

Figure 5. Effect of quarry fines on compressive strength of concrete at 350 kg/m^3

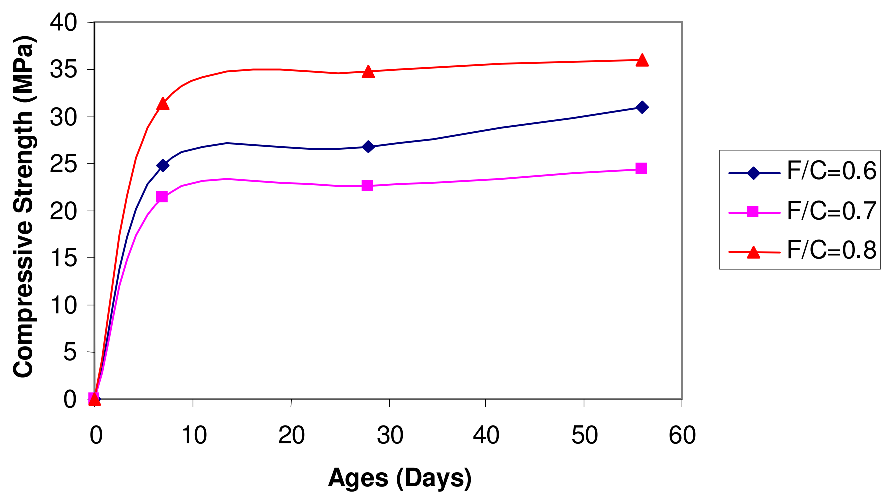

Figure 6. Reference compressive strength of concrete at 400 kg/m^3.

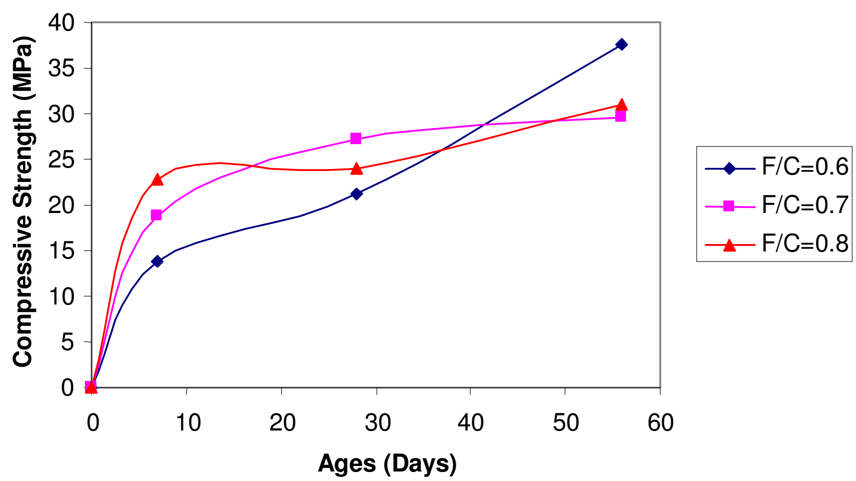

Figure 7. Effect of quarry fines on compressive strength of concrete at 400 kg/m^3.

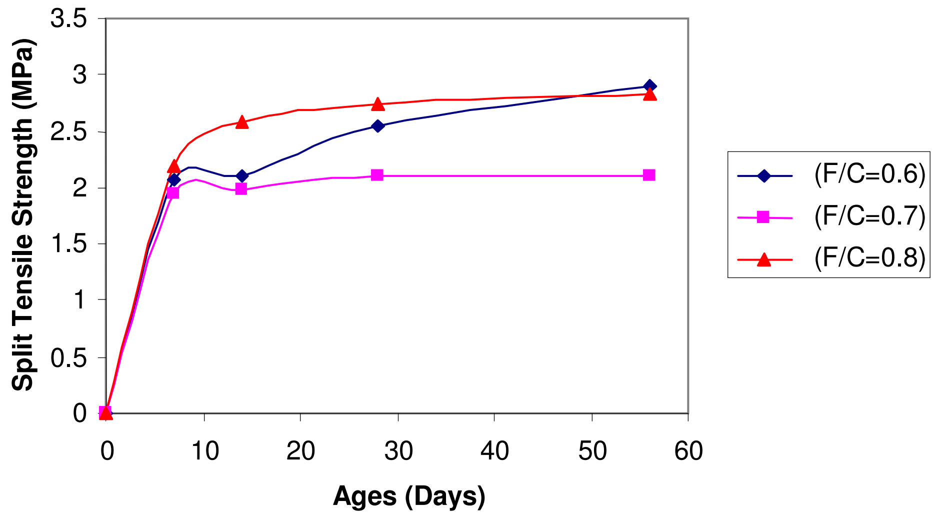

Figure 8. Reference split tensile strength concrete at 300 kg/m^3.

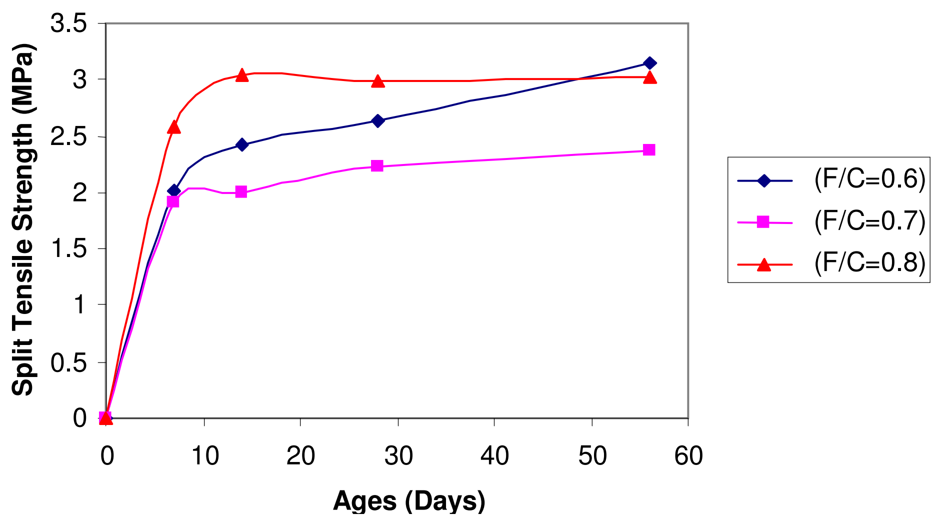

Figure 9. Effect of quarry fines on split tensile strength of concrete at 300 kg/m^3.

aggregate ratio. Whereas, for a binder content of 350 kG/m^3 the compressive strength of concrete (100% replacement of sand with quarry dust) ranged between 23.76 to 36.46 MPa. The maximum compressive strength was observed to be 36.46 MPa at 56 days for an F/C ratio of 0.6. The reference compressive strength of concrete specimens ranged between 31.50 to 39.60MPa. The maximum compressive strength of reference concrete was 39.6 MPa at 56 days for F/C of 0.6. It was also noted that at a binder content of 400 kg/m^3 the 56 days compressive strength (100% quarry dust) was 10.7% higher than all other concrete mixtures. From the experimental test results it can be inferred that with an increase in quarry dust percentage the strength was found to be increasing upto an optimal value of the fine to coarse aggregate ratio of 0.6.

Effect of quarry dust on split tensile strength

The split tensile properties of concrete specimens with and without quarry dust for different binder content and F/C ratio were shown in Figures 8 to 13. It was observed from the experimental test results that for a binder content of 300 kg/m^3, the split tensile values varied from 1.91 to 3.15 MPa and a maximum split tensile strength of 3.15 MPa was observed at 56 days for an F/C ratio of 0.6. Similarly for a binder content of 350 kg/m^3, the maximum split tensile strength varied from 2.48 to 3.33 MPa (Table 4). In general, maximum split tensile strength of 3.33 MPa was obtained for quarry dust concrete with an F/C ratio of 0.6. The addition of quarry dust has shown significant increase compared to plain cement concrete with natural sand. This can be safely concluded that

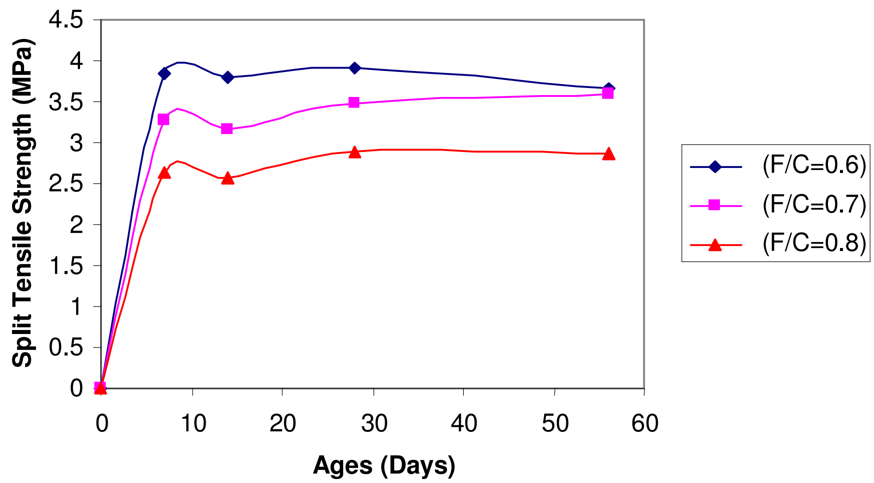

Figure 10. Reference split tensile strength concrete at 350 kg/m^3.

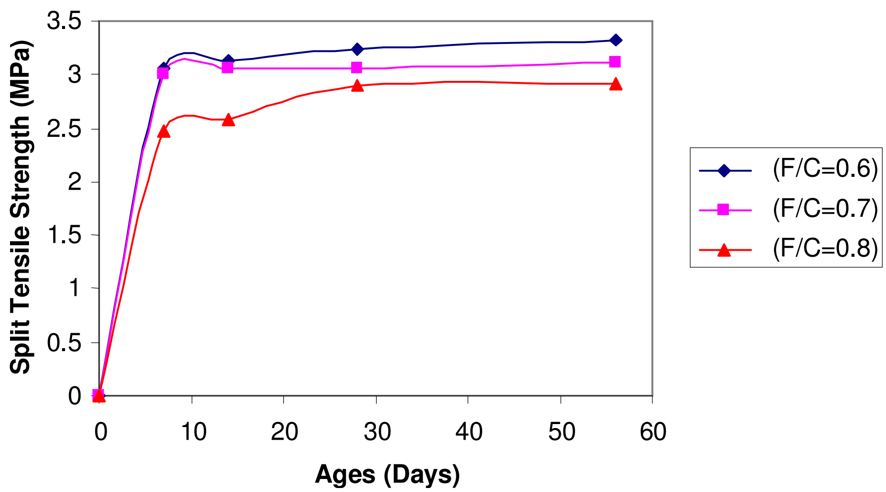

Figure 11. Effect of quarry fines on split tensile strength of concrete at 350 kg/m^3.

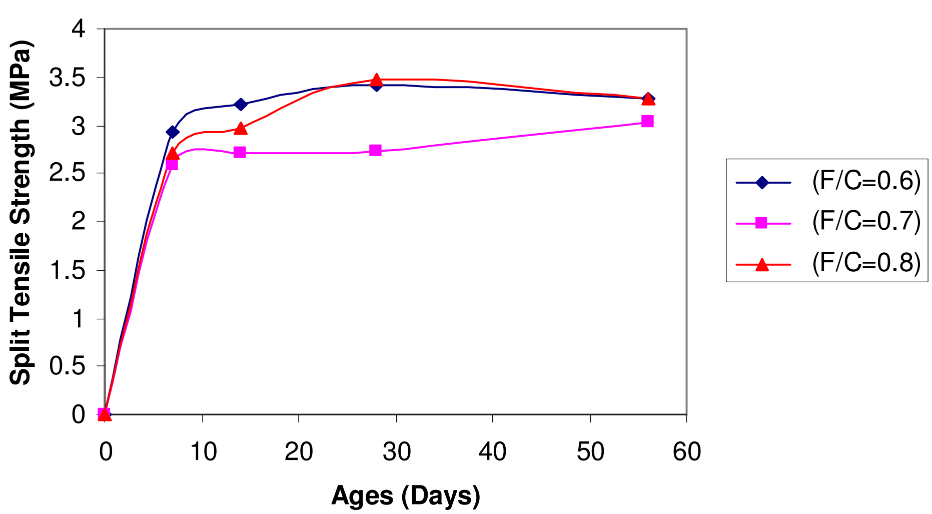

Figure 12. Reference split tensile strength concrete at 400 kg/m^3.

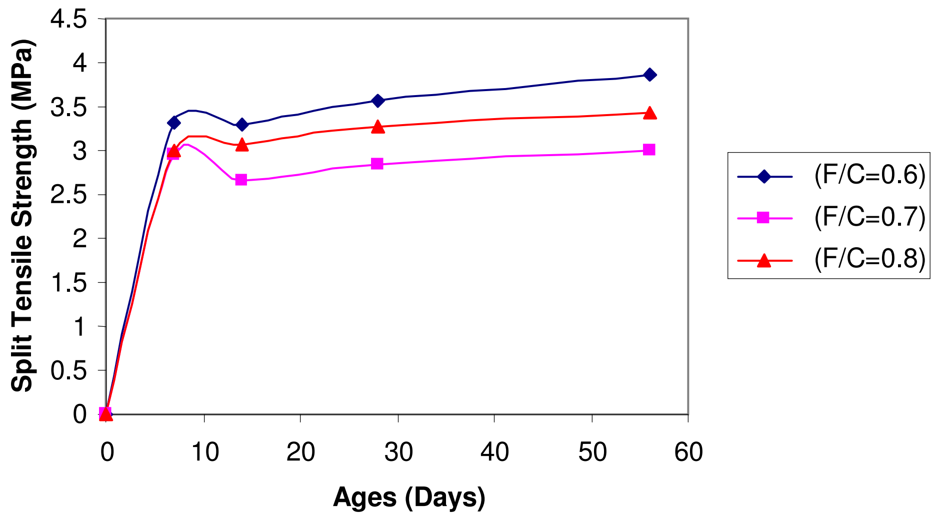

Figure 13. Effect of quarry fines on split tensile strength of concrete at 400 kg/m^3.

Table 4. Split tensile strength results of various concrete specimens.

Mix ID	Cement (kg/m^3)	F/C (kg/m^3)	Compressive strength of concrete (MPa)							
			without quarry dust				with quarry dust			
			7 days	14 days	28 days	56 days	7 days	14 days	28 days	56 days
Mix 1	300	0.6	2.07	2.10	2.55	2.90	2.02	2.42	2.64	3.15
		0.7	1.94	1.97	2.10	2.10	1.91	1.99	2.23	2.37
		0.8	2.2	2.58	2.73	2.83	2.58	3.64	2.99	3.03
Mix 2	350	0.6	3.85	3.79	3.92	3.66	3.06	3.14	3.23	3.33
		0.7	3.28	3.15	3.47	3.66	3.00	3.06	3.06	3.12
		0.8	2.64	2.58	2.90	2.87	2.48	2.58	2.90	2.91
Mix 3	400	0.6	2.93	3.21	3.41	3.28	3.33	3.29	3.57	3.87
		0.7	2.58	2.71	2.74	3.02	2.94	2.66	2.85	3.01
		0.8	2.71	2.96	3.47	3.28	2.99	3.07	3.26	3.42

quarry dust concrete can lead to significant improvement in microstructure due to different size fractions. Also, the filler effects of quarry dust can lead to significant increase (18.6%) in the split tensile strength compared to reference concrete.

Effect of quarry dust on modulus of elasticity

The modulus of elasticity of concrete with and without quarry dust for different binder content and F/C ratio are presented in this section. The results of elasticity modulus of concrete are shown in Figures 14 to 31. At 300 kg/m^3, the maximum elastic modulus of 29.31 GPa was obtained for an F/C ratio of 0.6. The elasticity modulus of concrete for 100% replacement of sand with quarry dust varied from 14.27 to 29.31 GPa. For the reference concrete, the maximum modulus of elasticity of concrete is 33.03 GPa at 56 days for an F/C ratio of 0.7 (Table 5). At 350 kg/m^3, the maximum modulus of elasticity of concrete (100% replacement of sand with quarry dust) ranged from 14.27 to 28.87 GPa. It can be noted that the effects of quarry dust on elastic modulus was observed at a binder content of 400 Kg/m^3 and had showed 15% higher than other concrete specimens. The effects of quarry dust on the elastic modulus property were found to be consistent with conventional concrete containing natural sand.

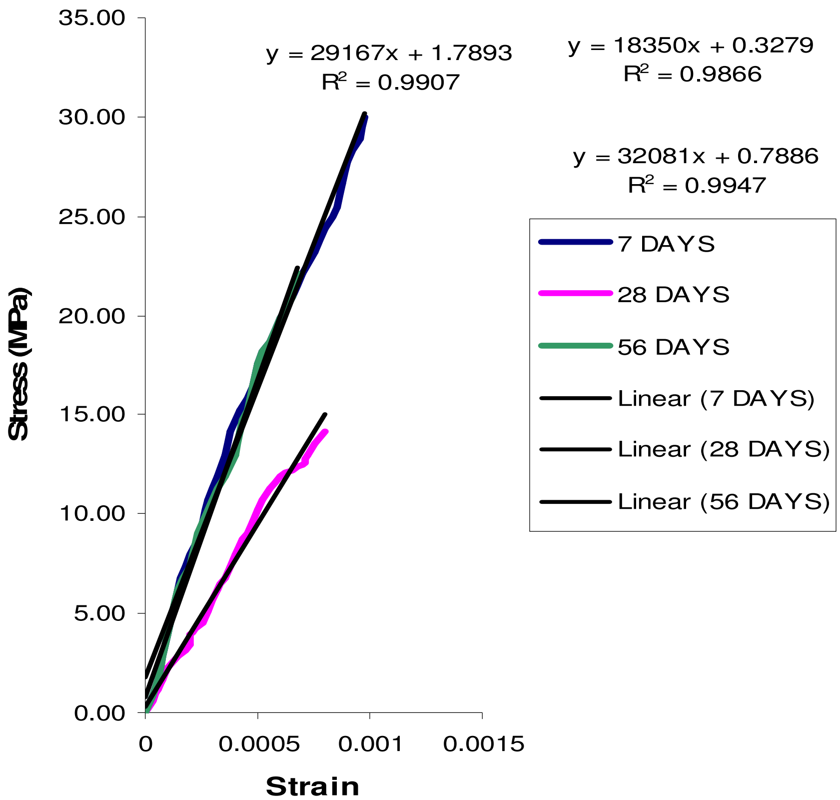

Figure 14. Reference modulus of elasticity 300 kg/m^3 at F/C=0.6.

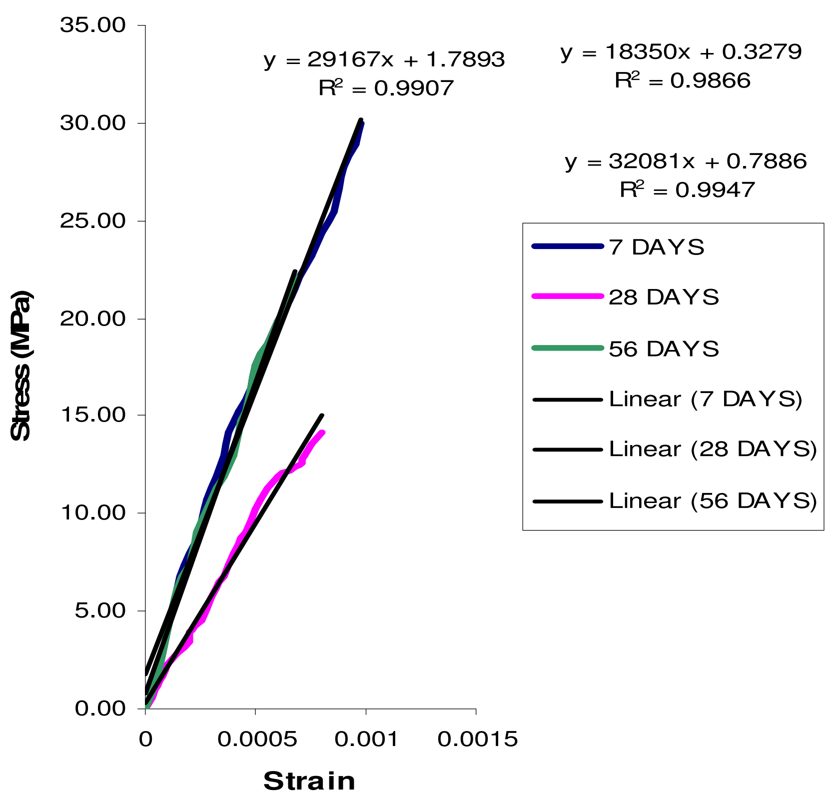

Figure 15. Effect of quarry fines on modulus of elasticity 300 kg/m^3 at F/C=0.6.

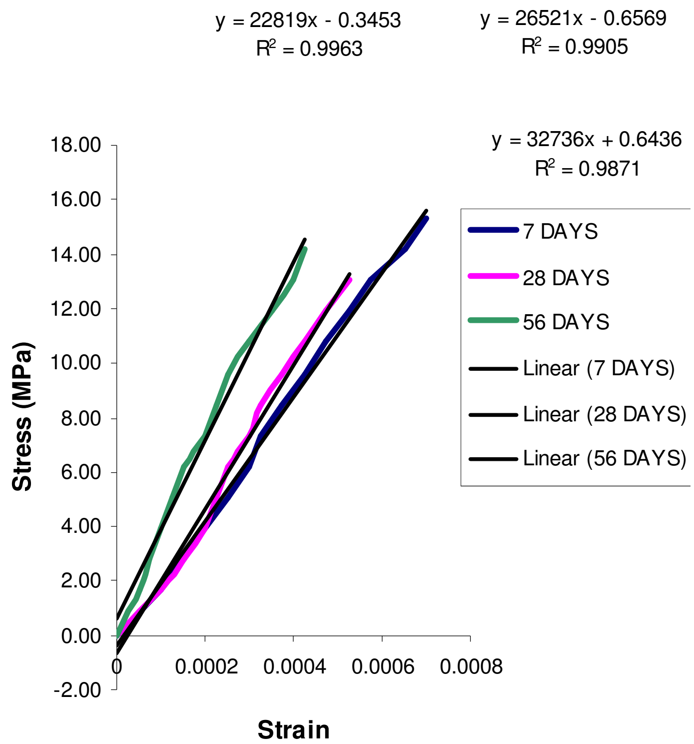

Figure 16. Reference modulus of elasticity 300 kg/m^3 at F/C=0.7.

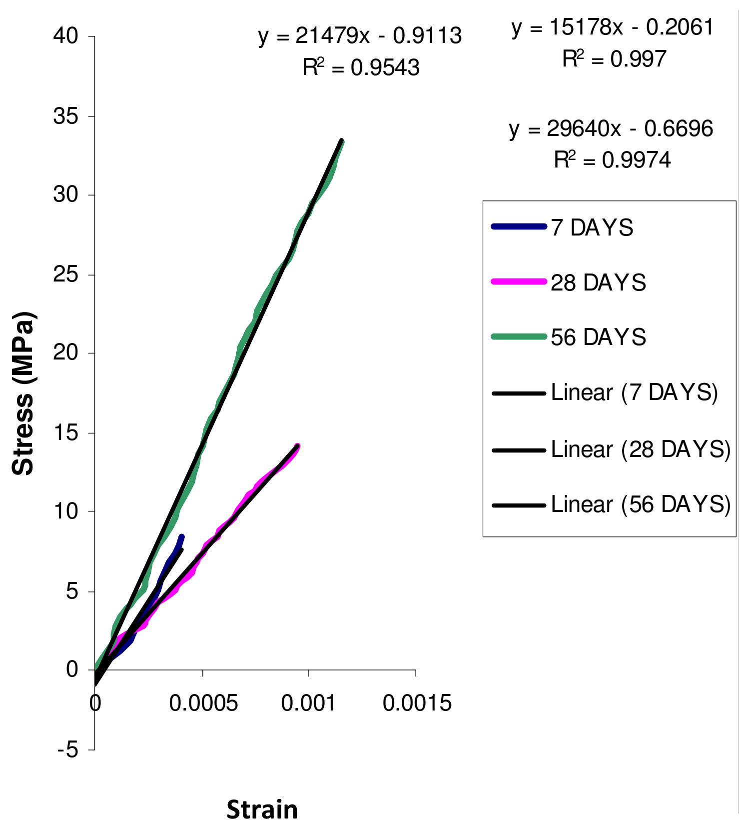

Figure 17. Effect of quarry fines on modulus of elasticity 300 kg/m^3 at F/C=0.7.

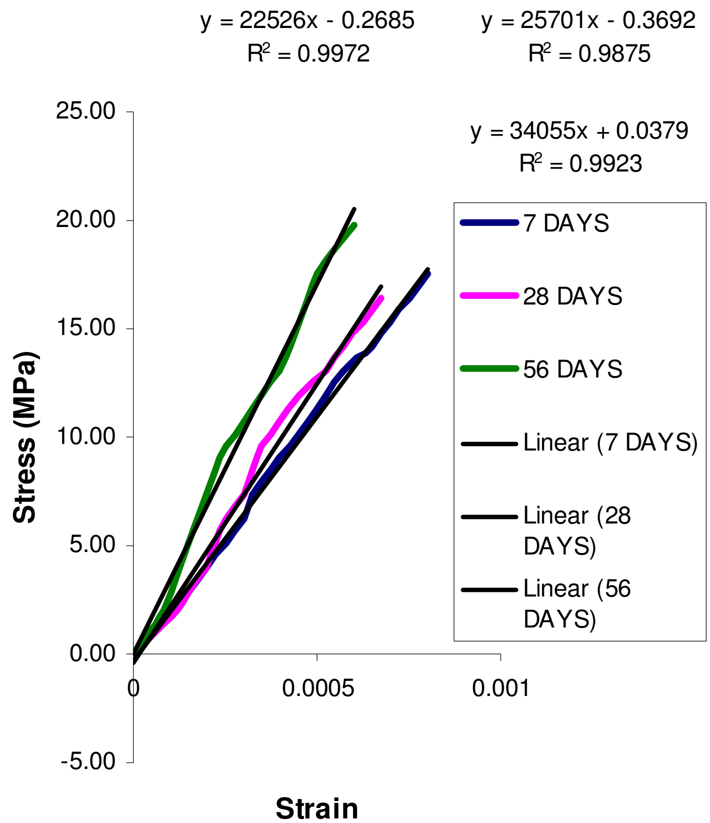

Figure 18. Reference modulus of elasticity 300 kg/m^3 at F/C=0.8.

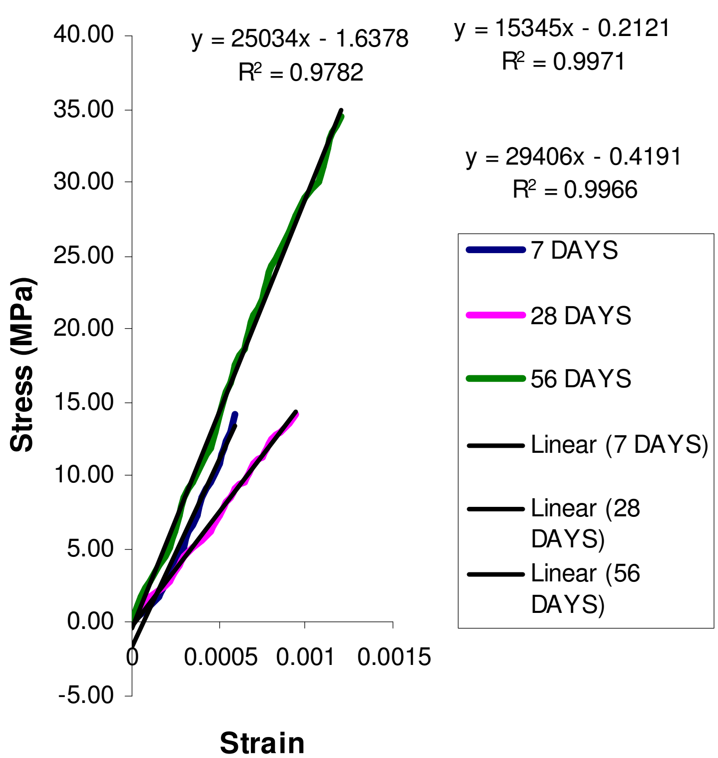

Figure 19. Effect of quarry fines on modulus of elasticity 300 kg/m^3 at F/C=0.8.

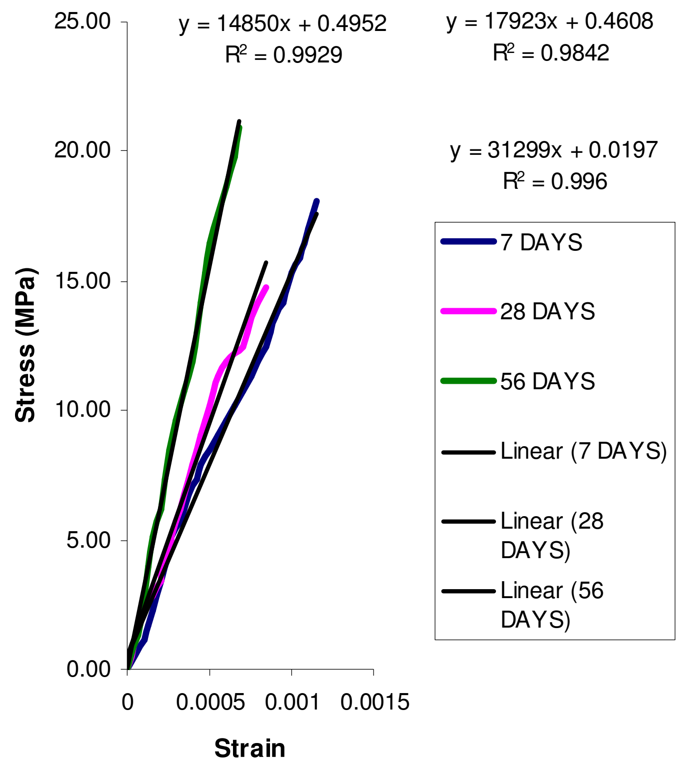

Figure 20. Reference modulus of elasticity 350 kg/m^3 at F/C=0.6.

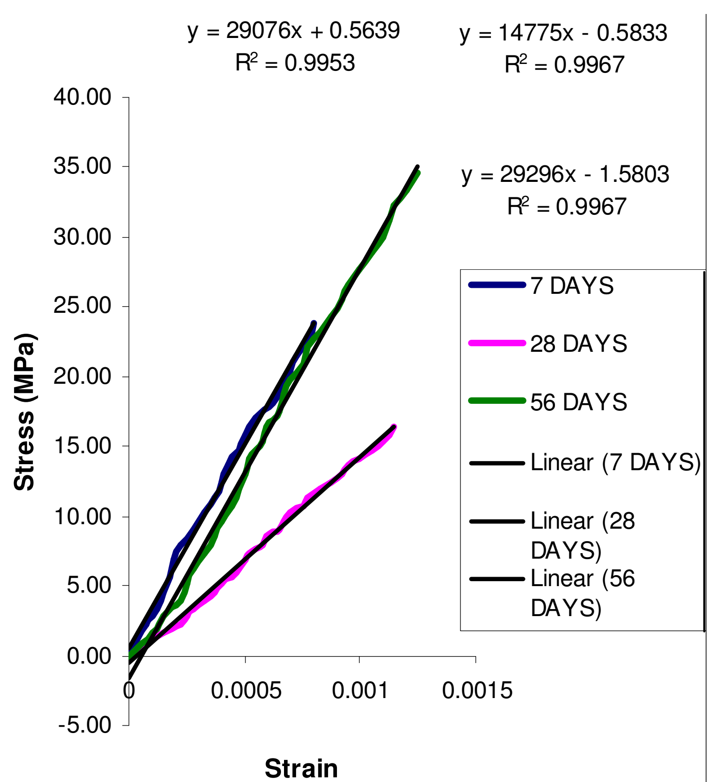

Figure 21. Effect of quarry fines on modulus of elasticity 350 kg/m^3 at F/C=0.6.

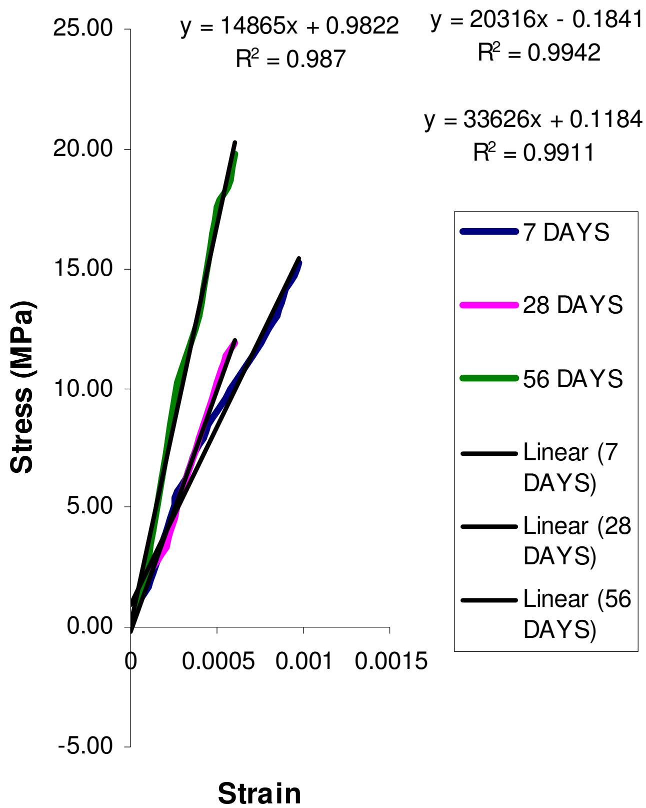

Figure 22. Reference modulus of elasticity 350 kg/m^3 at F/C=0.7.

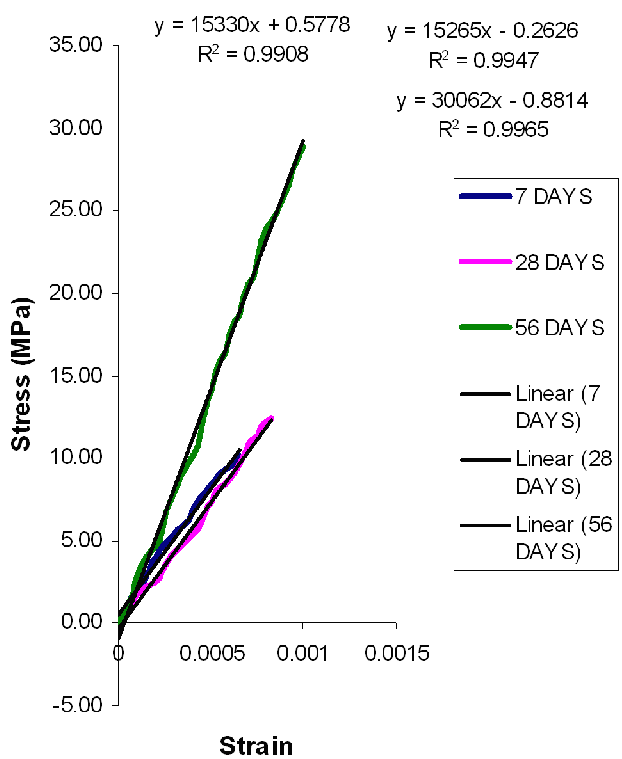

Figure 23. Effect of quarry fines on modulus of elasticity 350 kg/m^3 at F/C=0.7.

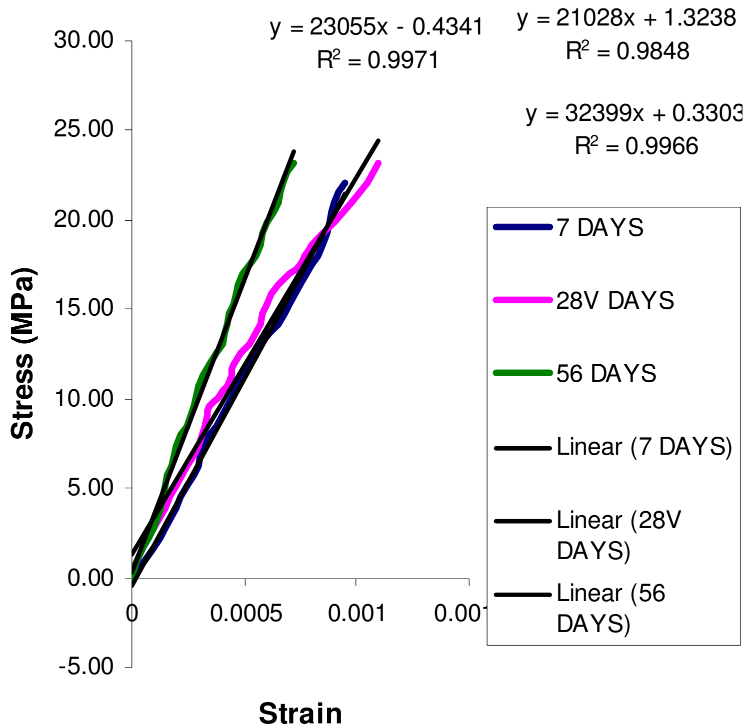

Figure 24. Reference modulus of elasticity 350 kg/m^3 at F/C=0.8.

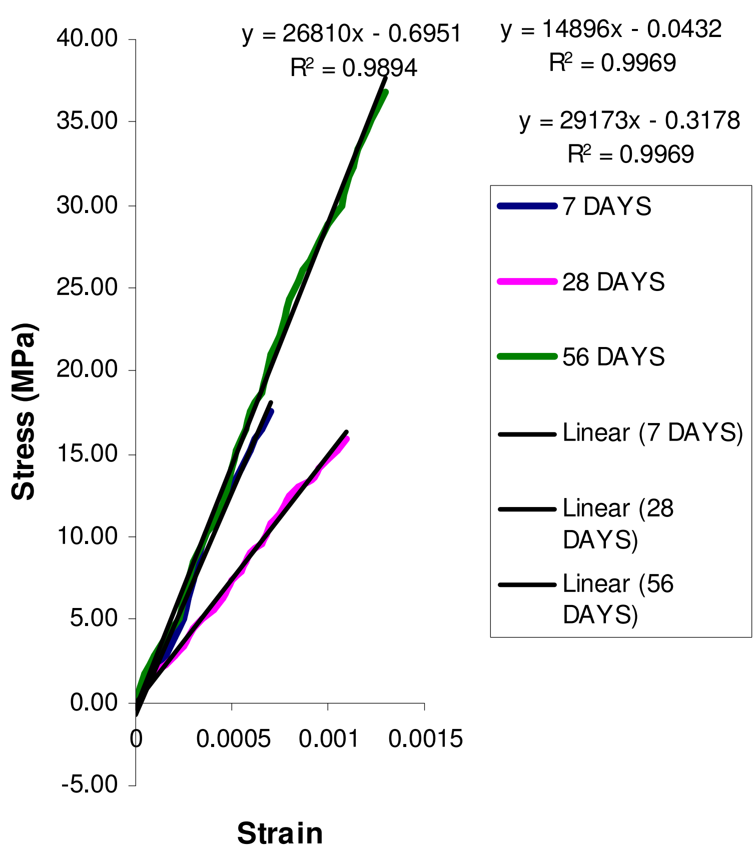

Figure 25. Effect of quarry fines on modulus of elasticity 350 kg/m^3 at F/C=0.8.

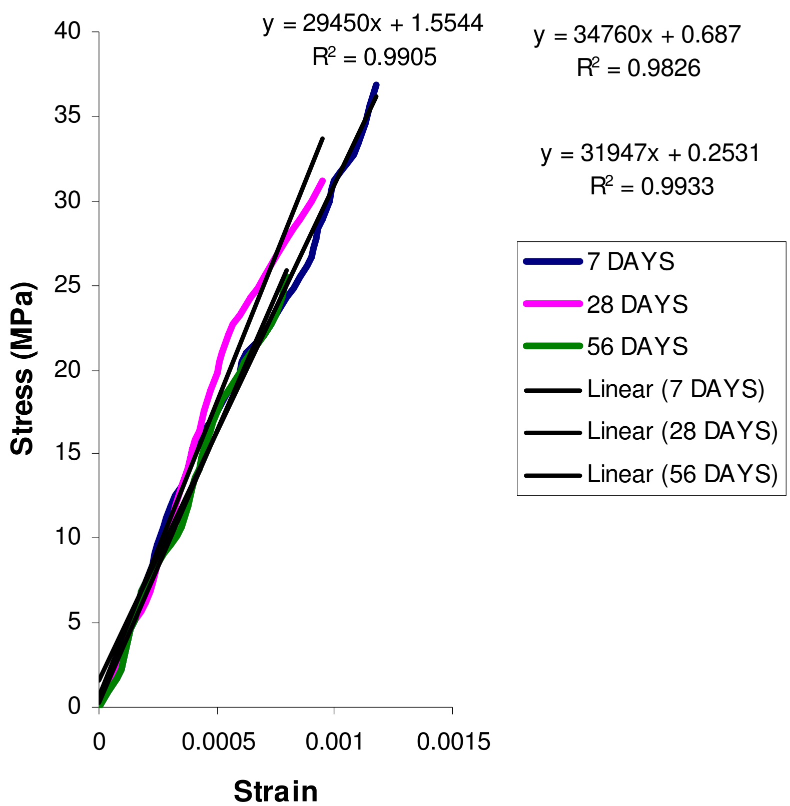

Figure 26. Reference modulus of elasticity 400 kg/m^3 at F/C=0.6.

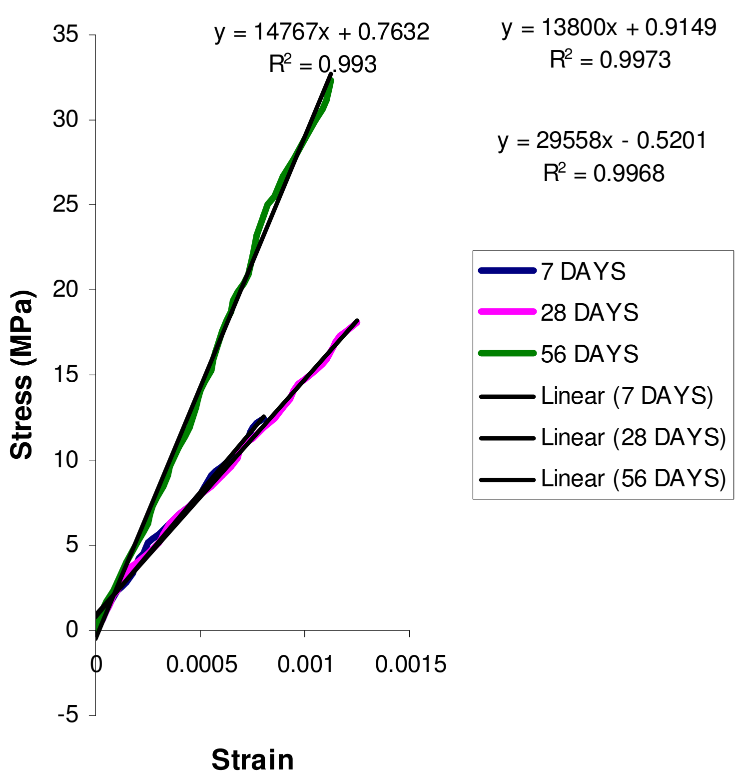

Figure 27. Effect of quarry fines on modulus of elasticity 400 kg/m^3 at F/C=0.6.

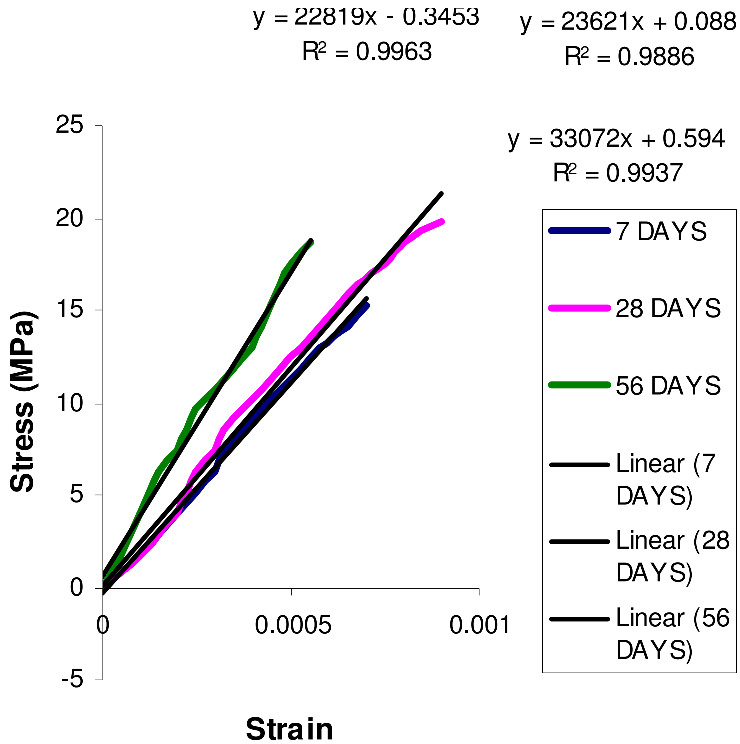

Figure 28. Reference modulus of elasticity 400 kg/m^3 at F/C=0.7.

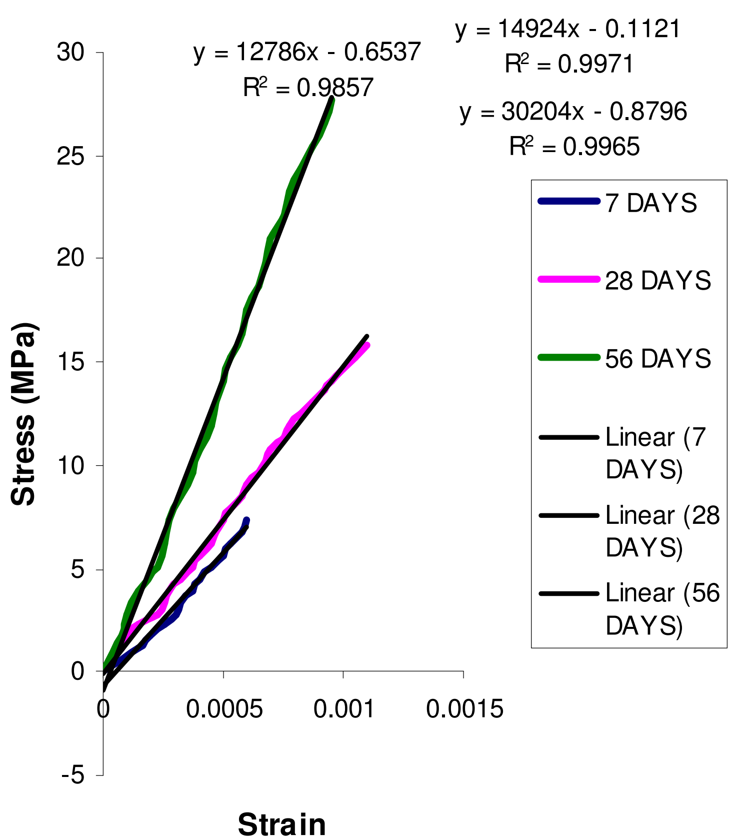

Figure 29. Effect of quarry fines on modulus of elasticity 400 kg/m^3 at F/C=0.7.

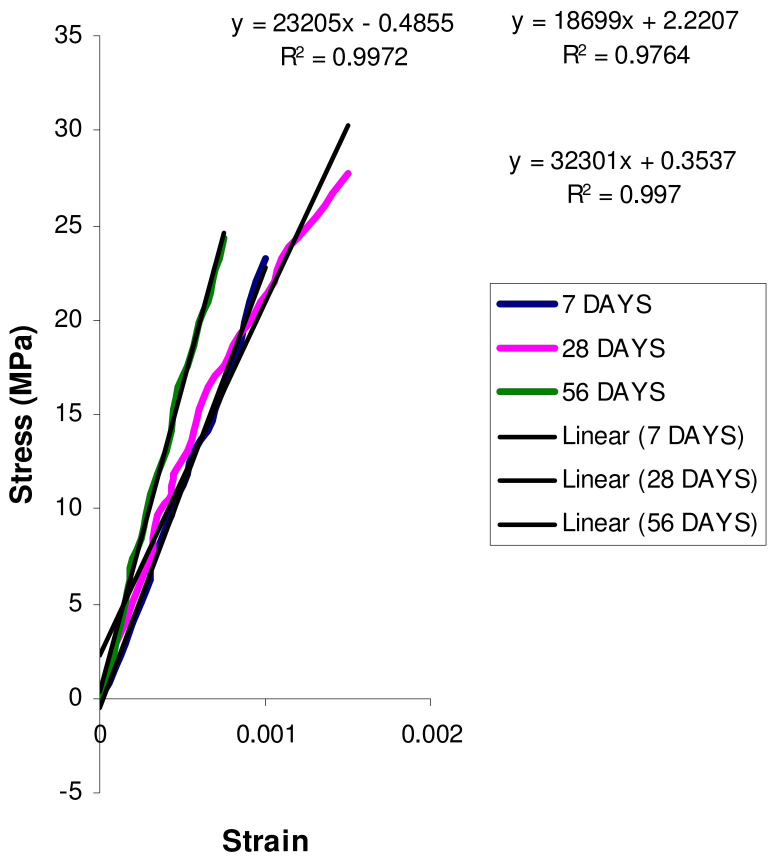

Figure 30. Reference modulus of elasticity 400 kg/m^3 at F/C=0.8.

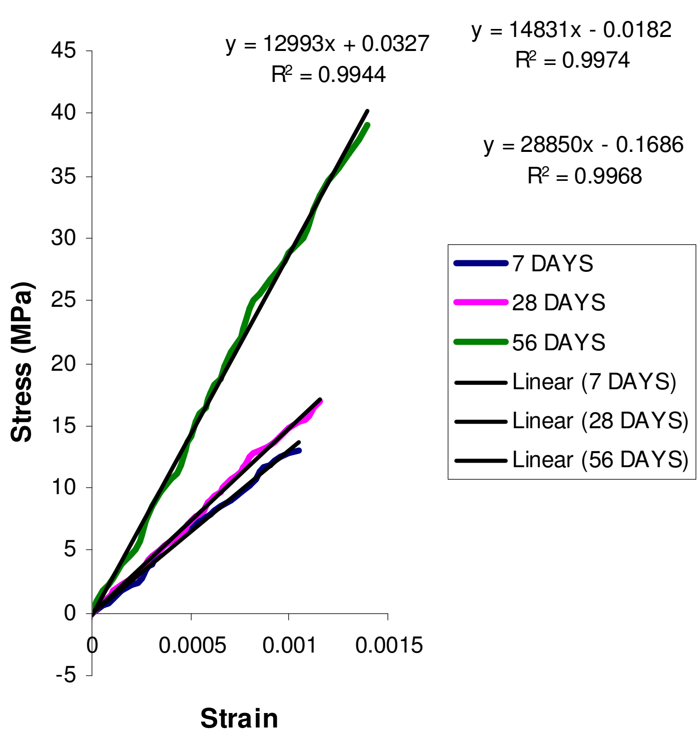

Figure 31. Effect of quarry fines on modulus of elasticity 400 kg/m^3 at F/C=0.8.

Table 5. Modulus of elasticity of concrete for various concrete specimens.

Mix ID	Cement (kg/m^3)	F/C (kg/m^3)	Modulus of elasticity of concrete (GPa)					
			without quarry dust			with quarry dust		
			7 days	28 days	56 days	7 days	28 days	56 days
		0.6	30.77	17.69	32.71	30.49	21.0	28.53
Mix 1	300	0.7	21.84	24.80	33.33	21.23	14.90	29.05
		0.8	21.94	24.32	33.03	23.59	14.89	28.78
		0.6	15.09	27.74	31.45	29.31	14.27	27.67
Mix 2	350	0.7	15.68	19.81	33.03	15.67	15.09	28.87
		0.8	23.24	21.10	32.02	25.07	14.40	28.31
		0.6	31.30	32.78	31.84	15.56	14.49	28.68
Mix 3	400	0.7	21.84	22.02	33.97	12.27	14.41	29.21
		0.8	23.21	18.49	31.85	12.40	14.76	27.90

Conclusion

The analysis of experimental data showed that the addition of the quarry dust improved the strength properties of concrete which was on par with that of conventional concrete. From above testing results, it is inferred that the quarry dust may be used as an effective replacement material for natural river sand. The increase of cement content in the mortar phase shows an increase in the strength. The fine quarry dust tends to increase the amount of superplasticizers needed for the quarry mixes in order to achieve the rheological properties. The 28 days compressive strength of 100% replacement of sand with quarry dust of mortar cube (CM 1:1) is 11.8% higher than the controlled cement mortar cube. The 56 days maximum Compressive strength for 100% replacement of sand with quarry dust of 400 kg/m^3 at F/C=0.6 was 17.45% higher than the reference concrete. At 56 days the maximum split tensile strength 100% replacement of sand with quarry dust of 400 kg/m^3 at F/C=0.6 was 15.25% higher than the reference concrete. The maximum modulus of elasticity at 100% replacement of sand with quarry dust of 300 kg/m^3 at F/C=0.6 is 10.24% higher than the reference concrete. When the quarry dust has high fineness, its usage in the normal concrete is limited because it increases the water demand.

REFERENCES

Celik T, Marar K (1996). Effects of crushed stone dust on some properties of concrete, Cement Concrete Res., 26(7):1121-1130.

De Larrard F, Belloc A (1997). The influence of aggregate on the compressive strength of normal and high-strength concrete. ACI Mater J., 94(5):417–426.

Galetakis M, Raka S (2004). Utilization of limestone dust for artificial stone production: an experimental approach. Miner. Eng., 17:355–357.

Gambhir ML (1995). Concrete Technology-Second Edition, Tata McGraw-Hill Publishing Company Limited, New Delhi.

Goble CF, Cohen MD (1999). Influence of aggregate surface area on mechanical properties of mortar. ACI Mater. J., 96(6):657–662.

IS: 516-1959. Indian Standard Methods of Test for Strength of concrete. Bureau of Indian Standards, New Delhi.

Nevillie AM (2002). Properties of Concrete –Fourth and Final Edition, Pearson Education Limited, Essex.

Safiuddin M, Zain MFM, Mahmud MF, Naidu RS (2001). Effect of quarry dust and mineral admixtures on the strength and elasticity of concrete, Proceedings of the Conference on Construction Technology, Kota Kinabalu, Sabah, Malaysia, pp. 68-80.