Modern Applied Science
www.ccsenet.org/journal.html
Vol. 3, No. 2
February 2009

Studies on the Performance of Quarry Waste in Flowable Fly Ash-Gypsum Slurry

Revathi .V.
K.S.R. College of Engineering
Tiruchengode, Tamilnadu - 637 215, India
Tel: 98-6544-2862 E-mail: revthiru2002@yahoo.com
Dr. Narasimha. V. L.
Pondicherry Engineering College
Pondicherry-605 014, India
Tel: 94-4353-7995 E-mail: narasimhavl@yahoo.com
Dr. Jayanthi. S.
Government College of Technology
Coimbatore, Tamilnadu-641 013, India
Tel: 98-9405-5758 E-mail: jaigct@yahoo.co.in

Abstract

Mining the sand, from riverbed is hazardous to environment. The deep pits dig in the riverbed for sand mining effects on ground water level and erode the nearby land. Most of the provincial Governments in India have imposed ban on mining sand from riverbeds. In such a situation the quarry waste can be an alternative to river sand .The present paper deals with the experimental investigation on the performance of quarry waste in fly ash gypsum slurry. The flow ranges selected for the study are 500± 25mm, 425± 25mm, 375±25mm, 300±50mm, & 150±50mm. The content of the quarry waste in the mix was increased from 0% to 50% for each of the above flows. Twenty mixes were proportioned and used in the study. These mixes were evaluated for flowability and compressive strength. Results indicate that quarry waste in fly ash gypsum slurry showed satisfying performance and suitable for a wide range of applications.

Keywords: Quarry waste, Fly ash, Gypsum, flowable slurry, CLSM, Activation

1. Introduction

Increased sand mining not only affects the aquifer of the river bed but also causes environmental problems. Digging of sand from river bed reduces percolation of rain water and interrupts the recharge of ground water table. The rain water as it passes through sand bed gets filtered and pure water will reach the water table. Uncontrolled mining of sand expose the natural soil to the running water. This will alter the river dynamics. River starts to scour the exposed soil and make banks unstable. In the backdrop of the above many provincial Governments have imposed ban on sand mining from river beds. In such a situation quarry waste from crushers are being used as an alternative to river sand.

Crushed stone is a prosaic but nearly indispensable construction material. About 3 billion tones are produced worldwide from a great variety of rock type. Residue form stone crusher called as quarry waste, a by-product in the production of crushed coarse aggregate. This residue generally represents less than 1% of aggregate production.

This quarry waste is dumped in forest areas, destroying the natural vegetation and ecology of the area and adversely affecting the fertility of the soil, contaminating water sources and contributing to drainage problems. It is possible to use the quarry waste as fine aggregate in construction industry in replacement of natural river sand. This will reduce not only the demand for natural sand but also the environmental burden. (Nagaraj.et.al, 1996, Narasimhan.et.al, 1999)

However, the literature on use of quarry waste is in the budding stage. This paper focuses on the use of quarry waste in flowable slurry.

Flowable slurry is a self compacting, cementitious material used primarily as a backfill material in place of compacted fill. Flowable slurry has a specified compressive strength of 8.3MPa or less at the age of 28-days. If future excavation is desired the compressive strength should be less than 2.1MPa. It is also referred as controlled low strength material (CLSM), flowable fill, controlled low density fill etc. In recent decades flowable slurry has gained momentum due to its wide variety of applications and several advantages. The applications include filling utility trenches, building excavations, underground storage tanks, abandoned sewers and utility lines, underground mine shafts and pavement sub-bases/bases. Flowable slurry provides an excellent opportunity to make use of industrial waste materials. (ACI Commimittee 229R, 1994).

High fly ash slurry consists of fly ash, 4 to 5% cement and enough quantity of water to produce the flowability required for particular application. High fly ash slurry was successfully used in filling underground structures. (William C.Krell,1989, Tarun Naik et.al,1990& Bruce.et.al, 1994)

Low fly ash mixes normally consists of high percentage of filler material/fine aggregate, a low percentage of fly ash and cement and enough water to obtain the desired flowability. The amount of cement, fly ash, fine aggregate and water is in the range of 3%, 8%, 72% and 17% by weight of total mix respectively (W.E.Brewer, 1994). The successive case histories such as protecting ground water form contamination, protecting ground river banks, culverts, drainage ditches and bridges from damaging effects of moving water has been documented on use of low fly ash flowable slurry. (Ronald L.Larsen, 1990, Zhongjie Zhang, 2007)

Waste foundry sand, a by-product of the metal casting industries was used as a fine aggregate in flowable slurry. The excavatability slurry was developed with desirable properties using foundry sand as a replacement for fly ash up to 85%. The permeability values ranged from 10^{-5} to 7 x 10^{-6} cm/sec (Bhat.et.al, 1996, Tarun Naik.et.al 1997, Paul.J.Tikalashy et.al, 1998 & 2000)

Phospho gypsum, a by-product in the production of phosphoric acid in the manufacture of fertilizers was used along with class C fly ash. S.Gandham, 1996 was suggested that it provided adequate flowability, strength and stability characteristics. In order to reduce long term liability associated with ash disposal site, pond ash was used in flowable slurry formulation in place of fly ash. The pond ash slurry was not recommended for structural fill (Christine A.Langton.et.al, 1998).

The use of flue gas desulphurization (FGD) ash was used as a replacement for conventional fly ash in flowable slurry. The properties were comparable with normal flowable slurry in terms of place ability, compressive strength and excavatability. FGD flowable fill with addition of additives and admixtures compared favorable with the characteristics of conventional quick-set flowable fill (Butalia.et.al, 2001).

The potential use of cement kiln dust (CKD) which is a fine powdery by-product of Portland cement manufacturing was used in flowable slurry. It is reported that CKD could be beneficially added to produce a very low strength material that offered comparable strength to soils used for conventional fills and many other low strength applications. (Pierce.et.al, 2003, M.Lacheme.et.al, 2008)

The potential use of scrap tire rubber could be utilized as light weight aggregate in flowable fill in the construction of bridge abutment fills, trench fills and foundation fills. C.E.Pierce& M.C. Blackwell, 2003)

The feasibility of using bottom ash as flowable slurry was investigated. Results showed that blending bottom ash with fly ash was a suitable method for developing acceptable flowable slurry. (J.P.Won.et.al, 2004)

Amnon Katz and Koveler, 2004 investigated the use of industrial by-products for the production of flowable slurry. Five different by-products such as cement kiln dust, dust from asphalt plants, coal fly ash, coal bottom ash and quarry waste were used. The results indicated that flowable slurry with good properties could be made with significant amounts of cement kiln dust (25 to 50% by weight).

Ata.G.Doven and Ayse Pekrioglu, 2005 developed structural fill using high volume fly ash with cement, lime, silica fume, high range water reducer and water. The experimental results showed that this composite material could be effectively used as a structural fill.

The effects of prolonged mixing and retempering (remixing) on flowable slurry were investigated by Sarah.l.et.al, 2001. They found that prolonged mixing did not change flowability or bleeding but time of setting was increased. Retempering did not significantly impact the material in the fluid state and 28-day strength.

Effect of curing condition on strength development of flowable slurry was investigated by Kevin.J.Folliard.et.al, 2003. They found that flowable slurry mix containing class C fly ash exhibited a significant increase in strength when cured under the highest temperature of 38°C.

The effect of water quality on the strength of flowable fill mixes was evaluated by Al.Harthy.et.al, 2005. Water samples were obtained from four major oil fields in Oman. The results indicated that use of non-fresh water produced low compressive strength in comparison with potable water. David Trejo.et.al, 2005 evaluated the corrosion performance of iron pipes and galvanized pipes completely embedded in flowable slurry. The results indicated that corrosion activity was less than pipes embedded in sand/soil/clay.

Being a pozzolanic material fly ash is normally activated by ordinary Portland cement. Many investigations showed that OPC might be replaced by alkalies and sulphates (industrial by-product/ reagent grade) to obtain a binder with similar properties. Hence studies on the fly ash activated by industrial by-product chemicals and its use as a binder in CLSM will boost the large-scale utilization of fly ash and industrial wastes. (AmitavaRoy.et.al, 1992, C.S.Poonet.al, 2001, Narasimha,V.L et.al 1995, Revathi. V.et.al, 2005)

In the present study flowable fly ash gypsum slurry along with quarry waste was developed to propose for various applications. This paper focuses the influence of quarry waste in flowable fly ash gypsum slurry.

2. Experimental Program

2.1 Materials and Mix Proportions

This study included high calcium fly ash, gypsum and quarry waste. The fly ash was obtained from Neyveli Lignite Corporation (NLC). The gypsum used in this study was obtained from TANFAC Cuddalore, Tamil Nadu, India. Quarry waste with dust fraction passing through 4.75mm sieve and retained on 300μm sieve was used for this present study.

For the experimental investigation five different flow series flowable fly ash gypsum slurry mixes were considered. The mixes were proportioned for flow of 500± 25mm, 425± 25mm, 375±25mm, 300±50mm, & 150±50mm. A total of twenty different fly ash gypsum slurry mixes were proportioned. Of these, five were the control mixes without quarry waste and the remaining had three different quarry waste content (10, 30 %and 50% by weight of binder, fly ash + gypsum). The gypsum content in the binder was 10% by weight of fly ash. The details of mixes are presented in table.1

2.2 Determination of flowability

Mixing of materials for both dry and wet mixes, were done mechanically. The prepared slurry was filled in an open ended cylinder 75mmdia x 150mm long (3"ϕ x 6"). The cylinder was slowly lifted and the slurry was allowed to spread. Spread of the slurry was measured using a metallic scale in two different directions.

2.3 Determination of compressive strength of F-G slurry

Immediately after measuring the spread the slurry was remixed and casted into 50mm cubical moulds. Cubes were de-mould after 24 hours and humid cured until testing. Twelve specimens were prepared, cured and tested for each mix.

3. Results and Discussions

3.1 Flow test

Flow tests were conducted for all the mixes with W/B ratios 0.30 to 0.82. The results obtained shown in figure 1. From the results obtained the following are noted.

The flow behaviour of F-G slurry is a very important property. Therefore it is essential to understand how different ingredients of the slurry affect this behaviour. Water is the main responsible for flow. The amount of water required to produce flow depends primarily on the proportions of fly ash, gypsum and quarry waste in the mix. The effect on flow of increasing quarry waste content is understood from the flow figure.1.

Water content for 'A' series mixes varied from 0.65 to 0.82 to obtain the flow of 500± 25 mm. Water content for 'B' series mixes was found as 0.60 and remained same for all quarry waste content to obtain a flow of 425 ± 25 mm. Water content for 'C' series was found as 0.50 for 0% and 10% quarry waste content, for 30% it was found as 0.55 and for 50% it was found as 0.57 to obtain a flow of 375 ± 25 mm. Water content for 'D' series mixes varied from 0.40 to 0.50 to obtain a flow of 300 ± 50 mm flow. Water content for 'E' series mixes varied from 0.30 to 0.45 to obtain a flow of 150 ± 50 mm flow.

During flow test it was found that 150 ± 50 mm flow was not readily flowable as other flow ranges. Water content for all flow ranges were found to increase with quarry waste content except 'B' series mixes. As the binder content increased the water demand decreased to obtain the desired flow.

3.2 Compressive Strength

Table.2 summarizes the test results of this study. As expected the compressive strength increased with age. The compressive strength for all flow range mixes with and without quarry waste ranged from 0.356 to 4.04 MPa at the age of 3-day, 1.41 to 6.20 MPa at the age of 7-day, 1.70 to 7.60 MPa at the age of 28-day and 2.72 to 7.61 at the age of 56-day. The strength obtained for all the mixes were below 8.3 MPa as specified by ACI 229 R. Therefore the strength requirement of flowable slurry was satisfied. All the mixes may be used as structural fills (Strength between 0.69 to 8.3MPa).

Figures.2 shows the effect of quarry waste on the relative compressive strength of F-G slurry at 28 days. It was clearly shown that there was optimum quarry waste for the compressive strength at 28-day. All flow ranges indicate that 10% quarry waste content as the optimum mix composition. At the optimum composition 300mm flow mix showed the higher improvement in compressive strength at the age of 28-day compared to other flow mixes.

The compressive strength of F-G slurry depended on the flowability of different mixes. Mixes at the normal flowability indicated high strength when compared with high flowable mixes. Beyond 425mm flow series mixes caused significant reduction in strength. However there was a significant increase in strength up to 3-day when compared with 425mm flow series mixes. Most of the mixes showed significant strength gain within 7-day. However, no significant strength improvement was observed for the period from 28-day to 56-day.

4. Conclusion

Industrial waste materials such as fly ash, gypsum and quarry waste were used in the preparation of flowable slurry. From the results obtained the following is concluded.

F-G slurry satisfies the requirements of the ACI Committee 229R as a CLSM. FG slurry can be an economic viable material to conventional compacted fill. The experimental results indicated that the quarry waste can be effectively used in fly ash gypsum slurry. Increase in quarry waste content increases the water requirement except 425±25mm flow mixes. Mixes with 50% quarry waste content for corresponding 500±25mm flow and mix without quarry waste corresponding to 425±25mm flow can be excavated using any mechanical equipment. All the mixes can be used as structural fill except 30% and 50% quarry waste content mixes corresponding to 500±25mm flow. The flowable fly ash gypsum slurry with quarry waste is environment friendly as it uses only industrial by-products.

References

ACI Committee 229R, (1994). Controlled Low Strength Materials (CLSM). *ACI Concrete International.* (July) 16(7), 55-64.

Al-Harthy, A.S., Taha, R., Abu-Ashour, J., Al-Jabri, K., & Al-Orami, S. (2005). Effect of water Quality on the Strength of Flowable Fill Mixtures. *Cement & Concrete Composites,* 27, 33-39.

Amitava Roy., Paul Schilling., Harvill C., Eaton., & Roger, K. Seals. (1992). Alkali activation of Class C flyash. *Proc. Utilization of Waste materials in Civil Engineering Construction, ASCE National Convention, New York*, (Sep) 13-17, 104-115.

Amnon Katz., &Konstantin Kovler. (2004). Utilization of Industrial by products for the production of Controlled Low Strength Materials (CLSM). *Waste Management,* 24, 501-521.

Ata.G.doven., & Ayse Pekrioglu. (2005). Material Properties of High Volume Fly ash Cement Paste Structural Fill. *Journal of Materials in Civil Engineering*, (Dec) 17(6), 686-693.

Bhat, S.T., & Lovell, C.W. (1997). Mix Design for Flowable Fill. *Transportation Research Record,* 1589, 26-28.

Brewer, W.E. (1994). Durability Factors Affecting CLSM. *SP 150-3, American Concrete Institute, Detroit, MI, USA*, 39 – 51.

Bruce, W.Ramme., Tarun, R.Naik., & Henry, J.Kolbeck. (1990). Use of fly ash slurry for underground facility construction. *Construction and Building Materials,* 8, (1), 63-67.

Butalia, T.S., Wolfe, W.E., Lee,J.W. (2001). Evaluation of a dry FGD material as a flowable Fill . *Fuel*, 80, 845-850.

Ceki Halmen., David Trejo., Kevin, J.Folliard & Lianxiang Du. (2005). Corrosion of Metallic Materials in Controlled Low-Strength Materials-Part 3. '*ACI Materials Journal* (Nov-Dec) 102(6), 429-437.

Charles, E.Pierce., Himanshu Tripathi., & Travis, W.Brown. (2003). Cement Kiln Dust in Controlled Low-Strength Materials. *ACI Materials Journal,* (Nov-Dec) 100(6), 455-462.

Christine, A.Langton., Rajendran, N., & Stanley, E.Smith. (1998). Use of Pond Ash in CLSM. *ACI Concrete International,*(Dec), 58-62.

David Trejo, Ceki Halmen, Kevin J.Folliard and Lianxiang Du, (2005). Corrosion of Metallic Materials in Controlled Low-Strength Materials-Part 4. *ACI Materials Journal,* (Jan-Feb) 103(3), 53-59.

David Trejo., Ceki Halmen., Kevin, J.Folliard., & Lianxiang Du. (2005). Corrosion of Metallic Pipe in Controlled Low-Strength Materials-Part 1 and Part 2. *ACI Materials Journal,* (May-June), 192-201.

Gandham, S., Seals, R.K., and Paul, T.Foxworthy. (1996). Phosphogypsum as a Component of Flowable Fill. *Transportation Research Record,* 1546, 79-87.

Kevin, J.Folliard., Lianxiang, Du., & David Trejo. (2003). Effects of Curing Conditions on Strength Development of Controlled Low Strength Material. *ACI Materials Journal,* (Jan-Feb), 100(1*),* 79-86.

Lachemi, M., Hossain, K.M.A., Shehata, M., & Thaha,W. (2008). Controlled low strength materials incorporating cement kiln dust from various sources. *Cement & Concrete Composites,* 30, 381-392.

Nagaraj, T.S., & Zahida Banu. (1996). Efficient Utilization of Rock dust and Pebbles in Portland cement concrete. *Indian Concrete Journal*, 70(1), 53-56.

Narasimha,.V.L., Sundararajan,T., & Ramalingam, C. (1995). Mix proportioning of FaL G Concrete Using Different

Quality Limes. *Proc of the Intl. Conference on Fly ash Disposal and Utilization, New Delhi,* 21 -22, III-25 to III-30.

Narasimhan,C., Patil, B.T., & Sannai,H. (1999). Performance of Concrete with Quarry dust as fine aggregate- An Experimental Study. *Civil Engineering and Construction Review*, 19-24.

Paul Tikalsky., Mike Gaffney., & Ray Regan. (2000). Properties of Controlled Low Strength material Containing Foundry Sand, *ACI Materials Journal* (Nov-Dec) 97(6l), 698-702.

Paul,J. Tikalsky., earl Smith., & Raymond Regan, W. (1998). Proportioning Spent Casting Sand in Controlled Low Strength materials. *ACI Materials Journal,* (Nov-Dec) 95(6), 740-746.

Pierce, C.E., & Blackwell, M.C. (2003). Potential of Scrap Tire Rubber as Lightweight Aggregate in Flowable Fill. *Waste Management,* 123(3), 197-208.

Poon, C.S., Kou, S.C., Lam, L., & Lin, Z.S.. (2001). Activation of fly ash/cement systems using calcium sulfate anhydrite $CaSO_4$). *Cement and Concrete Research,* 31,873-881.

Revathi, V., & Narasimha.V.L. (2005). Development and Characterization of Flowable High –Calcium Fly ash-Gypsum Slurry. *Indian Concrete Journal*, (Jan), 49-53.

Ronald, L.Larsen. (1990). Sound Uses of CLSMs in the Environment. *ACI Concrete International* (July) 12(7), 1-7.

Sarah, L.Gassman., & Charles, E.Pierce., & Aaron, J.Schroeder. (2001). Effects of Prolonged Mixing and Retempering on Properties of Controlled Low Strength Material (CLSM). *ACI Materials Journal,* (Mar-April), 98(2), 194-199.

Tarun, R.Naik., & Shiw, S.Singh.(1997). Flowable Slurry Containing Foundry Sands. *Journal of Materials in Civil Engineering,* (May), 93-102.

Tarun, R.Naik., Bruce, W.Ramme., & Henry, J.Kolbeck. (1990). Filling Abandoned Underground Facilities with CLSM Fly ash Slurry. *ACI Concrete International*. (July) 12 (7), 1-7.

William, C. Krell.(1989). Flowable Fly ash. *ACI Concrete International*. (November) 11(11), 54-58.

Won, J.P. Lee, Y.S. Park, C.G. & Park, H.G. (2004). Durability Characteristics of Controlled Low Strength Materials containing Recycled bottom ash. *Magazine of Concrete Research*, (Sep) 64 (7)), 429-436.

Zhongjie Zhang., & Mingjiang Tao. (2007). Flowable Fill as Geotechnical Material in Highway Cross-Drain Trenches. *Geotechnical Testing Journal,* 30(1), 1-6.

Table 1. Mix Proportions of Fly ash Gypsum slurry with quarry waste

Sl.No	Flow range	Mix Identity	Mix Ingredients						Flow/ Spread (mm)
			Fly ash (Kg/m^3)	Gypsum (Kg/m^3)	Quarry waste (Kg/m^3)	Water (Kg/m^3)	W/ (FA+ G)	Quarry waste (%)	
1	500 ± 25 mm flow	A_1	898.05	89.8	--	642.00	0.65	0	481.0
2		A_2	825.54	82.55	90.8	635.66	0.70	10	503.0
3		A_3	742.85	74.28	245.13	612.84	0.75	30	490.4
4		A_4	677.34	67.73	372053	610.95	0.82	50	491.0
5	425 ± 25 mm flow	B_1	941.26	94.126	--	621.23	0.60	0	420.0
6		B_2	907.88	90.78	99.86	599.08	0.60	10	405.0
7		B_3	845.93	84.59	279.15	558.31	0.60	30	404.0
8		B_4	791.42	79.14	435.28	522.33	0.60	50	405.0
9	375 ± 25 mm flow	C_1	1053.43	105.34	--	579.38	0.50	0	391.0
10		C_2	1008.82	100.88	110.97	554.85	0.50	10	387.0
11		C_3	889.31	88.93	293.47	538.03	0.55	30	397.0
12		C_4	809.44	80.94	445.19	507.51	0.57	50	380.0
13	flo w	D_1	1188.19	118.81	--	522.8	0.40	0	274.0

14		D_2	1100.39	110.03	121.04	514.43	0.43	10	262.0
15		D_3	932.89	93.28	307.85	513.08	0.50	30	294.0
16		D_4	829.03	82.9	455.96	501.56	0.55	50	280.0
17	150 ± 50 mm flow	E_1	1366.57	136.65	--	450.96	0.30	0	185.0
18		E_2	1212.38	121.23	133.36	466.76	0.35	10	133.0
19		E_3	983.83	98.383	324.66	486.99	0.45	30	185.0
20		E_4	867.61	86.76	477.18	477.18	0.50	50	183.0

Table 2. Compressive strength of various F-G slurry mixes

Sl. No	Flow range	Mix Identity	Quarry waste (% by weight)	Compressive Strength at various ages (MPa)			
				3 days	7 days	28 days	56 days
1	500±25mm flow	A_1	0	1.43	2.01	2.36	2.72
2		A_2	10	1.12	2.34	2.74	2.82
3		A_3	30	1.12	1.73	2.77	2.82
4		A_4	50	1.03	1.52	2.09	2.33
5	425±25mm flow	B_1	0	0.36	1.41	1.70	3.10
6		B_2	10	0.45	2.10	2.85	3.47
7		B_3	30	0.86	2.61	2.79	3.34
8		B_4	50	0.88	2.62	2.80	3.50
9	375 ± 25 mm flow	C_1	0	2.62	3.72	5.00	5.70
10		C_2	10	2.67	4.58	5.20	5.80
11		C_3	30	2.68	5.00	5.10	5.20
12		C_4	50	2.84	2.97	3.50	3.60
13	300 ± 50 mm flow	D_1	0	2.96	4.19	5.41	5.90
14		D_2	10	3.01	4.40	7.60	7.61
15		D_3	30	3.06	5.02	5.64	6.07
16		D_4	50	3.63	5.20	5.82	5.83
17	150 ± 50 mm flow	E_1	0	3.20	5.60	5.61	6.50
18		E_2	10	3.47	6.20	6.80	6.91
19		E_3	30	4.04	5.02	5.30	5.80
20		E_4	50	3.02	4.81	4.91	6.10

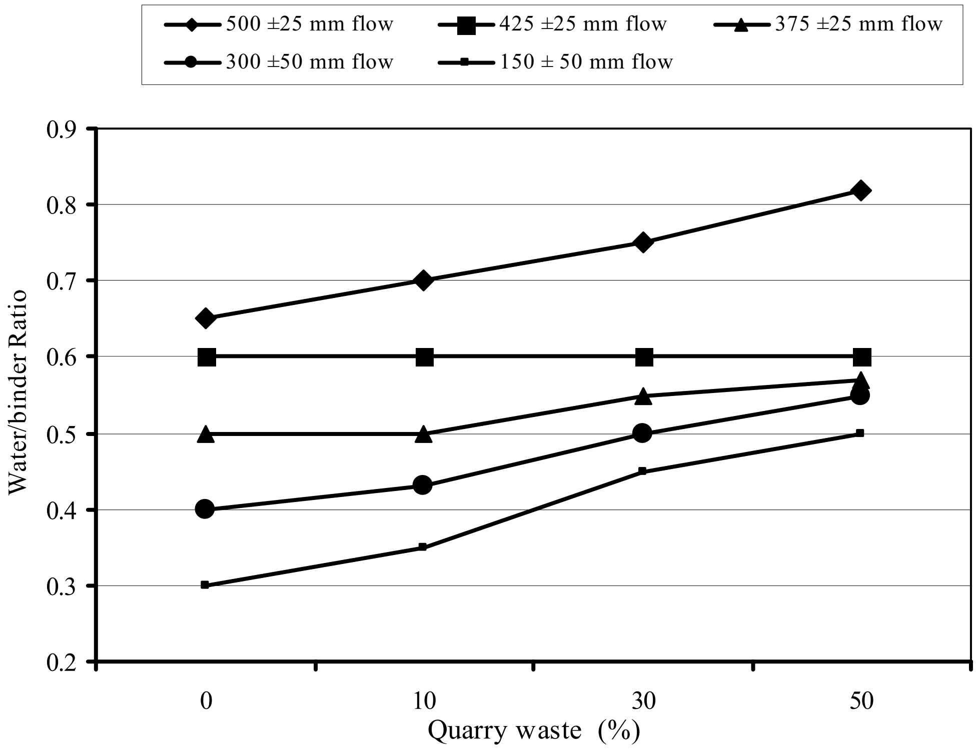

Figure 1. Water requirement for various Quarry waste Content

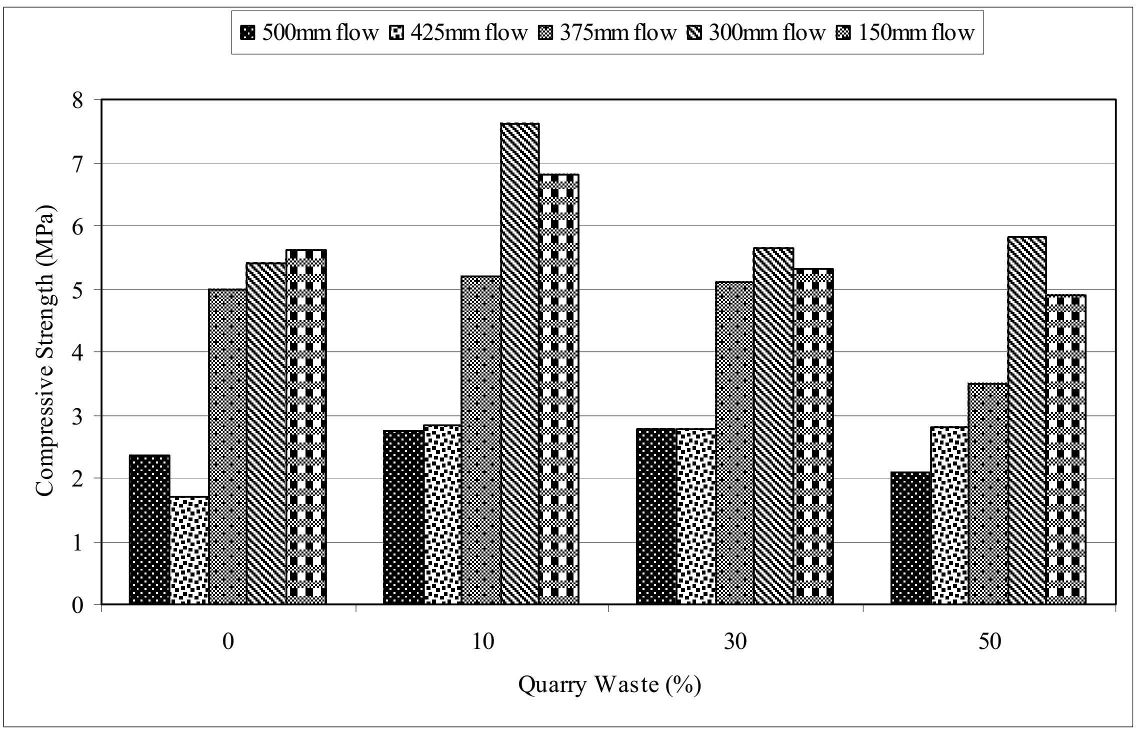

Figure 2. Effect of quarry waste on F-G slurry at 28 days Compressive Strength