==
Engineering & Technology in India www.engineeringandtechnologyinindia.com
Vol. 1:5 December 2016
==

Physical and Chemical characteristics of Dolomite for Partial Replacement of Cement in M_{20} Concrete

J. Satheesh Kumar, G. Palaniselvan, D. Jayganesh, & J. Vijayaraghavan
==

Abstract

Concrete is a construction material consisting of cementitious material, fine aggregate, coarse aggregate and water. Now a days the cost of these materials are increased so, we need to look at a way to reduce the cost of building materials especially cement. One of the recent advancement in construction industry is replacement of materials in concrete. The replacement of materials offers cost reduction, energy savings and protection of environment. To achieve the above objective we are partially replacing the cement with Dolomite. The present investigation is aimed to study the fresh and hardened properties of concrete when cement is partially replaced by Dolomite powder. The work is focused on M_{20} grades of concrete. The percentage of Dolomite powder that replaced cement in this investigation are 0%,5%,10%, 15% and 20% .The fresh property is workability and hardened properties are compressive strength, flexural strength, split tensile strength have been carried out with the evidence of FTIR, SEM, EDAX.

Keywords: Dolomite, compressive strength, split tensile strength, flexural strength, cement.

Introduction

Cement is one of the most important constituents of concrete. The manufacture of cement is calcining argillaceous and calcareous materials at a high temperature. During this process, large amount of CO_2 is released in to the atmosphere. It is estimated that the production of one ton of cement results in the emission of 0.8 ton of CO_2. The lowering of carbon dioxide and nitrogen oxides emission, due to the partial clinker replacement and the reduction of electric energy consumption, resulting from the better grindability of soft limestone component should are discussed as ecological reasons. The possibility of waste materials by-products disposal as additives to cement has been an important challenge improving the sustainable development of cement and concrete technology, as it has been pointed out by many researchers are reported Lothenbach [1], Giergiczny [2], Nocuń-Wczelik and Łój et al. [3].

The various report use of replacement materials such as fly ash and limestone in Portland cement has been gaining much attention in recent years [4–8]. The utilization of fly ash is one of the popular methods proposed to reduce expansion due to alkali–silica reactivity. Kamal M.M, et al [9] evaluated the bond strength of self compacting concrete mixes containing dolomite powder. Deepa Balakrishnan, et al [10] carried out an investigation on the workability and strength characteristics of self compacting concrete containing fly ash and dolomite powder. Bhavin K., et al [11] presented the details of the investigation carried out on paver blocks made with cement, dolomite block and different percentages of polypropylene fibres. Salim Barbhuiya [12] carried out an investigation to explore the possibilities of using dolomite powder for the production of SCC.

Dolomite is a carbonate material composed of calcium magnesium carbonate **$CaMg(CO_3)_2$.** Dolomite is a rock forming mineral which is noted for its remarkable wettability and dispersibility. Dolomite has a good weathering resistance. Dolomite is a preferred for construction material due to its higher surface hardness and density. Asphalt and concrete applications prefer dolomite as a filler material due to its higher strength and hardness. By the effective utilization of dolomite powder, the objective of reduction of cost of construction can be met. An attempt has been made to explore the possibility of using dolomite as a replacement material for cement. M_{20} grade concrete specimens were made by replacing 5, 10, 15, 20 and 25% of cement with dolomite powder. The Compressive, Split tensile and Flexural strength of the specimens were found on the 7^{th} and 28^{th} days. Optimal replacement percentage of dolomite was determined.

Experimental Method

Materials Used

Cement:

Ultra tech super grade cement confirming IS 8112:1989 was used thought the work. The cement used was dry and free from lump. All possible content was avoided while storing cement. Properties of this cement were tested and shown in table-1.

Table-1physical properties of cement

Properties	Results
Fineness	7%
Specific gravity	3.16
Standard consistency	31.6
Initial setting	150min
Final setting	270min

Fine Aggregate

The fine aggregate used in this work was clean river sand, whose maximum size is 4.75 mm, was used. The result of sieve analysis confirms to zone-II (according to IS: 383-1970). The other properties of fine aggregate are determined and shown in table -2.

Coarse Aggregate

Machine crushed aggregate of 20mm size is brought from quarry. Aggregates of more than 20mm size are separated by sieving. Tests are carried out in order to find out properties of it. The test results are presented in table- 2.

Table-2 Properties of fine aggregate & coarse aggregate

Properties	Fine Aggregate	Coarse Aggregate

Specific gravity	2.68	2.71
Fineness	Passing through 4.75mm sieve	Retained-4.75 mm sieve
Bulk density	1558.5kg/m3	1632.92kg/m3
Fineness modulus	3.16	7.12

Dolomite

Dolomite is a carbonate material composed of calcium magnesium carbonate **CaMg (CO3)2.** The term is also used to describe the sedimentary carbonate rock dolostone. Dolostone (dolomite rock) is composed predominantly of the mineral dolomite with a stoichiometric ratio of 50% or greater content of magnesium replacing calcium, often as a result of digenesis. Dolomite is a rock forming mineral which is noted for remarkable wettablity and dispersibility as well as moderate oil and plasticizers absorption. Dolomite has good weathering resistance. The properties of the dolomite powder are given in Table 3.

Table 3: Properties of Dolomite Powder

S. No	**Property**	**Dolomite Powder**
1.	Formula	CaMg $(CO_3)_2$.
2.	Specific gravity	2.85
3.	Color	White, grey to pink
4.	Tenacity	Brittle
5.	Mosisture contant(%)	Nil
6.	Crystal system	Trignal
7.	Sieve analysis	Zone II

Water

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. The water, which is used for making concrete should be clean and free from harmful impurities like oil, alkalis, acids etc. Water for making concrete should have pH between 6 and 8. Locally available drinking water was used in this work.

Details of Concrete Mix

In the present investigation, M_{20} mix was designed as per the guidelines given in IS 10262:2009. The water cement ratio adopted was 0.48. The quantities of cement, fine aggregate and coarse aggregate required for $1m^3$ of concrete are 399.13 kg, 526.56 kg, 1221.81 kg respectively.

Testing Procedure

The required water of standard consistency and setting time and volume expansion were examined according to TS-EN 196-3 [13]. The cement pastes were obtained using a mixer for 1 min at low speed (60 rpm) and 4 min at high speed (120 rpm). The paste was then poured into moulds creating 100×10×10 mm prisms. The samples were cured at 20 ± 2°C and 90 ± 2% relative humidity. The samples were then remolded and placed in deionized water. The cement paste specimens were cured for 2, 7, and 28 days, and then they were taken out of the water. The hydration process was stopped by grinding the hydrated samples with acetone and by washing the residue several times with more acetone. The samples were dried at 65°C.

The scanning electron microscopy studies, selected cement paste samples cured for 7 and 28 days were used. A cement prism was cut into cubes ≈10 mm square, one side of which was ground flat. The hydrated samples were flooded with acetone to stop hydration reactions. After drying and coating with gold the SEM image of samples were obtained using a ZEISS SUPRA 55VP FESEM scanning electron microscope.

The FT-IR spectra of hydrated Portland cement and composite cement pastes were recorded on a Bruker Vertex 70 FT-IR spectrometer equipped with the harric MVP2- unit in the range of 4000–500 cm^{-1} region.

Result and Discussion

Compressive Strength

Compressive strength was determined using compression testing machine (CTM) of 2000 KN capacity. Compressive test was carried out on 150 mm × 150 mm cube specimen for which three cubes were prepared for each mix. Strength of each cube was evaluated after 7, 14, and 28 days respectively.

Compressive Test for 7 days

For 10% replacement of WGP obtained greater strength when compared to other % of replacement in 7 days.

Dimension of specimen : 150mm × 150mm × 150mm

Days of curing : 7 days

Table 4. Compression test on cubes for 7 days

S.NO	Type of specimen % of dolomite powder	Compressive					
		Load in 10^3N			Strength in N/mm^2		
		Trial 1	Trail 2	Mean	Trail 1	Trail 2	Mean
1	Conventional	220	216	218	3.10	3.06	3.04
2	5%	164	158	161.6	2.33	2.24	3.24
3	10%	230	270	250	3.25	3.81	3.72
4	15%	375	315	290	5.33	4.40	4.10
5	20%	204	203	203.5	2.88	2.87	2.76

Compressive Strength Test for 28 days

For 10% replacement of WGP obtained greater strength when compared to other % of replacement in 28 days.

Dimension of specimen : 150mm × 150mm × 150mm

Days of curing : 28 days

Table 5. Compression test on cubes for 28 days

S.NO	Type of specimen % of dolomite powder	Compressive					
		Load in 10^3N			Strength in N/mm^2		
		Trial 1	Trail 2	Mean	Trail 1	Trail 2	Mean
1	Conventional	620	650	635	27.5	28.88	28.22
2	5%	675	705	690	30	31.33	30.66
3	10%	695	725	710	30.88	32.22	32.55
4	15%	560	600	580	24.88	26.66	25.77
5	20%	515	525	520	22.88	23.33	23.11

Split Tensile Strength

The split tensile strength test was conducted on cylindrical specimens of 150mm diameter and 300mm height cast and cured in the same manner as the cubes in the compressive test. Two wooden strips were placed, one at the top and the other at the bottom of the specimen.

Split Tensile Test for 28 days

For 10% replacement of WGP obtained greater strength when compared to other % of replacement in 28 days.

Dimension of specimen : 150mm × 150mm × 150mm

Days of curing : 28 days

Table 6. Compression test on cubes for 28 days

S.NO	Type of specimen % of dolomite powder	Split Tensile					
		Load in 10^3N			Strength in N/mm^2		
		Trial 1	Trail 2	Mean	Trail 1	Trail 2	Mean
1	Conventional	375	385	380	16.66	17.10	16.88
2	5%	390	410	400	17.33	18.22	17.77
3	10%	400	440	420	19.55	16.66	16.66
4	15%	395	415	405	17.55	18.44	17.98
5	20%	340	370	355	15.11	16.44	15.77

Flexural Strength

Flexural strength is the one which measures tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 6 × 6 inch (150 × 150-mm) concrete beams with a span length at least three times the depth. The flexural strength is expressed as Modulus of rupture (MR) in psi (MPa) and is determined by standard test methods of IS 516.

Flexural strength of concrete flexural MR is about 10 to 20 percent of compressive strength depending on the type, size, and volume of coarse aggregate used. However, the best correlation for specific materials is obtained by laboratory tests for given materials and mix design. The MR determined by third-point loading is lower than the MR determined by centre-point loading, sometimes by as much as 15%.

Flexural Strength Test for 28 Days

For 10% replacement of WGP obtained greater strength when compared to other % of replacement in days.

Dimension of specimen : 150mm × 150mm × 150mm

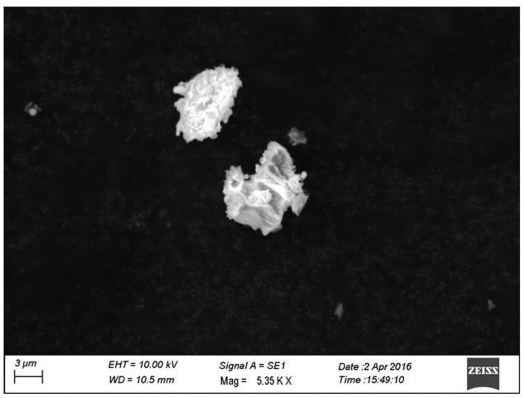
Days of curing : 28 days

Table 7. Compression test on cubes for 28 days

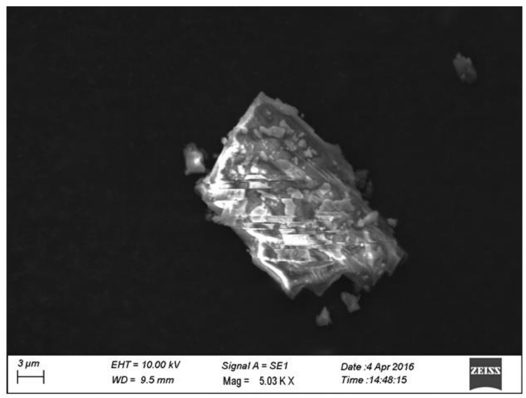
S.NO	Type of specimen % of dolomite powder	Flexural					
		Load in 10^3N			Strength in N/mm^2		
		Trial 1	Trail 2	Mean	Trail 1	Trail 2	Mean
1	Conventional	5.68	6.08	5.88	2.27	2.43	2.35
2	5%	10.08	9.78	9.92	4.03	3.90	3.97
3	10%	6.32	6.28	5.80	2.54	2.51	2.33
4	15%	4.32	3.84	4.08	1.73	1.54	1.63
5	20%	1.04	0.96	1.00	0.42	0.38	0.45

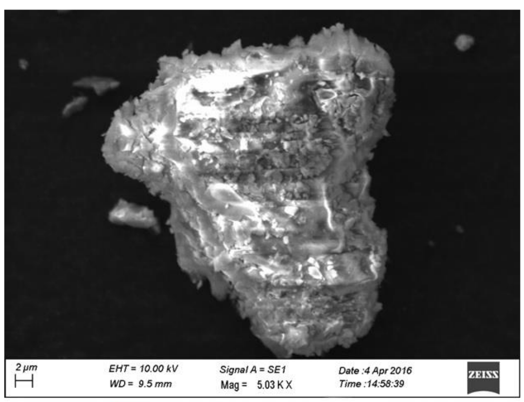
SEM Study

3a)Cement



3b)Dolomite





3c)Concrete mix

Fig. 3a. SEM images of cement

Fig. 3b. SEM images of dolomite

. Fig. 3c. SEM images of Concrete mix

Figs. 3a, 3b and 3c show that some microstructural characteristics of the Dolomite cement pastes cured for 28 days. As can be observed in these figures, the samples studied through SEM/EDX have quite different microstructures. In Dolomite - cement paste, significant quantity of ettringite $Ca(OH)_2$ (CH) crystals and a porous composite mass of calcium silicate hydrate are observed. Additionally, large amounts of the rectangle shape of Dolomite are seen everywhere. Due to covering of the Dolomite particles by the reaction products only a small number of round particles are distinguished. A significant quantity of ettringite is also evident in Dolomite-cement paste.

FT-IR analyses of hydrated cement

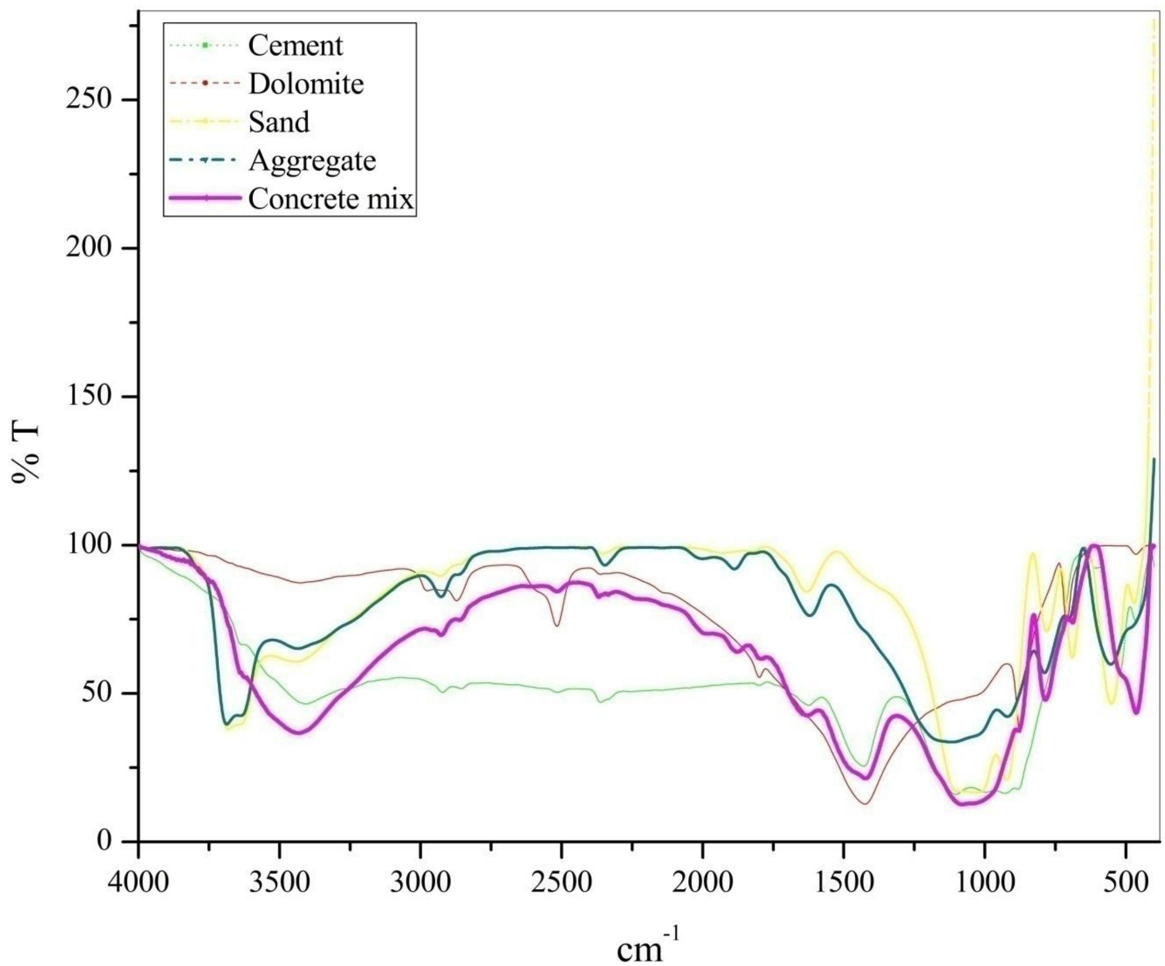


Fig. 4. FTIR Spectrum of cement composition: without additive and with dolomite additive.

The FTIR spectra of the Dolomite and cement hydrated up to 28 days are presented in Figs. 4. The major changes of the FTIR spectra in the hydrated cement pastes are:

(i) The strongest Si–O stretching band appears at 1089.59 cm^{-1}, and a weak one Si–O bending at about 463 cm^{-1} in all samples. However, the intensity of the Si–O stretching band is lower than that of the composite cement at 2 days curing ages.

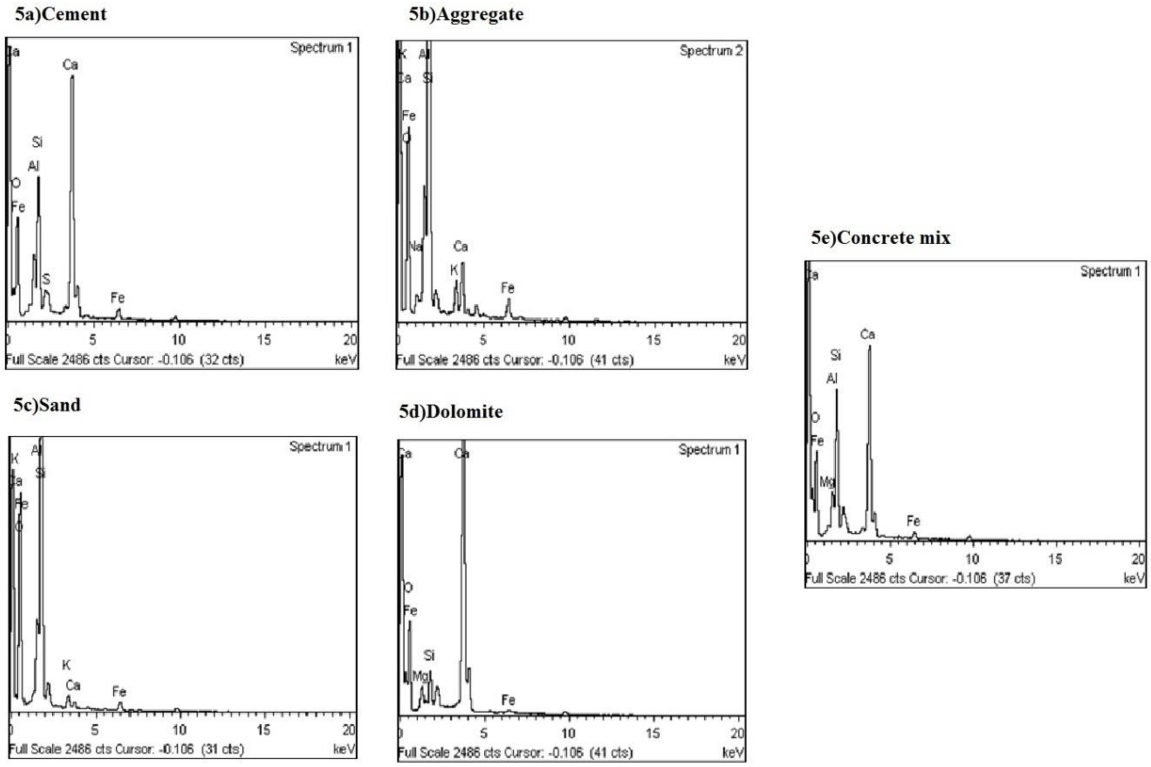
(ii) The relative intensity of the Si–O bending vibrations also undergoes significant changes as curing time is expanded.

(iii) The C–O bending vibration at about 882 cm^{-1} and the C–O stretching at around 1421 cm^{-1} are the characteristic band of CO_3^{2-}.

(iv) A broad band centered at ≈ 3400 cm^{-1} is due to symmetric and antisymmetric stretching vibration of water bound in the hydrations products.

(v) A small but defined peak appeared at 3831–3846 cm^{-1} can be attributed to the OH band from calcium hydroxide. The intensity of corresponding peak, in the samples containing a Dolomite is lower than that of the other tested sample.

EDX Analyses of Hydrated Cement



Energy dispersive X-ray (EDX) analysis is used for the determination of elemental composition and some of the specific elements in the adsorbent material, the figure. 5 and 6 of images shows that different peak positions and their elemental composition are Mg=1.93%,O=77.63%,Si=2.20%,Fe=0.26%.Ca=17.98%. After combination of cement and dolomite powder the concrete mixture the elemental composition also increased.

Conclusions

- At low percentage, from 5 to 15%, dolomite additive plays the role of active component or even acts as cement replacement. At higher amount the “dilution” effect occurs.
- The heat evolution process is not significantly altered in the presence of dolomite it means that setting of paste with dolomite additive is not retarded.

- The reactions dealing with water consumption and releasing some components to the liquid phase are accelerated in the presence of dolomite.
- The hydration of alite is accelerated.
- The application of dolomite material as a component of non - standard material, for example for geotechnology should be considered.
- Incorporation of 5%wt and more than 20%wt dolomite limestone into cement always reduces compressive strengths after 7 and 28 days. Specimens containing 10% dolomite limestone powder by weight have the maximal compressive strengths.

===

References

[1] Lothenbach B, Le Saout G, Gallucci E, Scrivener K. Influence of limestone on the hydration of Portland cements. *Cem Concr Res* 2008; 38:848-860.

[2] Giergiczny Z, Garbacik A, Pużak T, Sokołowski M. Cementy portlandzkie wieloskładnikowe CEM II/B-M(V-LL) 32,5R i CEM II/BM(S-V) 32,5R - właściwości i zastosowanie. Proc. of conference *Dni Betonu Tradycja i Nowoczesność*, Wisła, 2010; 155-164.(*in Polish*)

[3] Nocuń-Wczelik W, Łój G. Effect of finely dispersed limestone additives of different origin on cement hydration kinetics and cement hardening, Proc. *13th Int. Congress on the Chemistry of Cements*, Madrid 2011; abstract 235. CD

[4] Duchesne J, Berube MA. Effect of supplementary cementing materials on the composition of cement hydration products. Adv Cem Based Mater 1995; 2:43–52.

[5] Lam L, Wong YL, Poon CS. Degree of hydration and gel/space ratio of high-volume fly ash/cement systems. Cement Concrete Res 2000; 30:747–56.

[6] Shehata Medhat H, Thomas DA Michail. The effect of fly ash composition on the expansion of concrete due to alkali–silica reaction. Cement Concrete Res 2000; 30:1063–72.

[7] Lee CY, Lee HK, Lee KM. Strength and microstructural characteristics of chemically activated fly ash–cement systems. Cement Concrete Res 2003; 33:425–31.

[8] Voglis N, Kakali G, Chaniotakis E, Tsivilis S. Portland–limestone cement, their properties and hydration compared to those of other composite cement. Cement Concrete Compos 2005;27:191–6.
[9] S. Deepa Balakrishnan., and K. C. Paulose, “Workability and strength characteristics of self compacting concrete containing fly ash and dolomite powder”, American Journal of Engineering Research (AJER), Volume. 2, 2013, pp. 43-47.
[10] M. M. Kamal, M. A. Safan, and M. A Al- Gazzar, “Experimental Evaluation of Steel-Concrete bond Strength in Low-Cost Self-Compacting Concrete”, Concrete Research Letter, volume. 3(2), 2012, pp. 439-451.
[11] K. Bhavin, Kashiyani, Jayeshkumar pitroda, and K. Bhavnaben Shah, “Effect Of Polypropylene Fibers on Abrasion Resistance and Flexural Strength for Interlocking Paver Block”, International Journalof Engineering Trends and Technology(IJETT), Volume. 4, 2013, pp. 1837-1843.
[12] Salim Barbhuiya, "Effects of fly ash and dolomite powder on the properties of self-compacting concrete”, Construction and Building Materials,Volume. 25, 2011, pp.3301-3305.
[13] TS EN-196-1, TS EN-196-3, TS EN-196-6, TS-EN 197-1, Turkish National Standards, TSE Turkish Standard Institute, Ankara, Turkey.

==

J. Satheesh Kumar
Assistant Professor
University College of Engineering Ramanathapuram
Ramanathapuram 623 513
Tamilnadu
India

G. Palaniselvan
Assistant Professor
Department of Civil Engineering,
Syed Ammal Engineering College
Ramanathapuram 623 502
Tamilnadu
India

D. Jayganesh, Corresponding author
Assistant Professor

University College of Engineering Ramanathapuram
Ramanathapuram 623 513
Tamilnadu
India
jayganeshd2003@gmail.com

J. Vijayaraghavan
Assistant Professor
University College of Engineering Ramanathapuram
Ramanathapuram 623 513
Tamilnadu
India
drjvr1988@gmail.com