Dubai Central Laboratory

DCL Test Results

Trial Mix Program for EcoSmart Concrete

Tests completed by Dubai Central Laboratories
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Results Compiled by:

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Introduction

The EcoSmart Foundation is a Canadian non-profit organization promoting the use of higher levels of supplementary cementing materials (SCMs) in concrete to reduce the environmental footprint associated with it's creation. EcoSmart has done extensive work in Canada promoting the use of Fly Ash as a partial cement replacement and has over 20 case studies where cement has been replaced at levels up to 55%.

The Dubai Central Laboratories was established in 1997 with the aim of centralizing all the labs within Dubai Municipality under one department. DCL's mission is to carry out tests, research, product inspection, measurement and certification to agreed upon standards and regulations for the purpose of assuring confidence to their clients. DCL performs tests on various building materials and acts as a certification body for high quality materials.

As fly ash concretes are not commonly used in the United Arab Emirates' (UAE's) construction industry EcoSmart found it necessary to help create a body of scientific knowledge and literature on the topic of high volume fly ash (HVFA) mixes in the Gulf region. As part of this EcoSmart engaged DCL to perform a number of tests on fly ash concretes which examined various durability and mechanical characteristics of fly ash concretes within the Emirates' environment.

Mix Designs

A range of concrete mixes were designed based on the needs of the construction industry in the UAE. Low, medium and high strength concretes with 28 day strength targets of 40, 60 and 80 MPa were created based on mix designs proposed by EcoSmart contractors and partners.

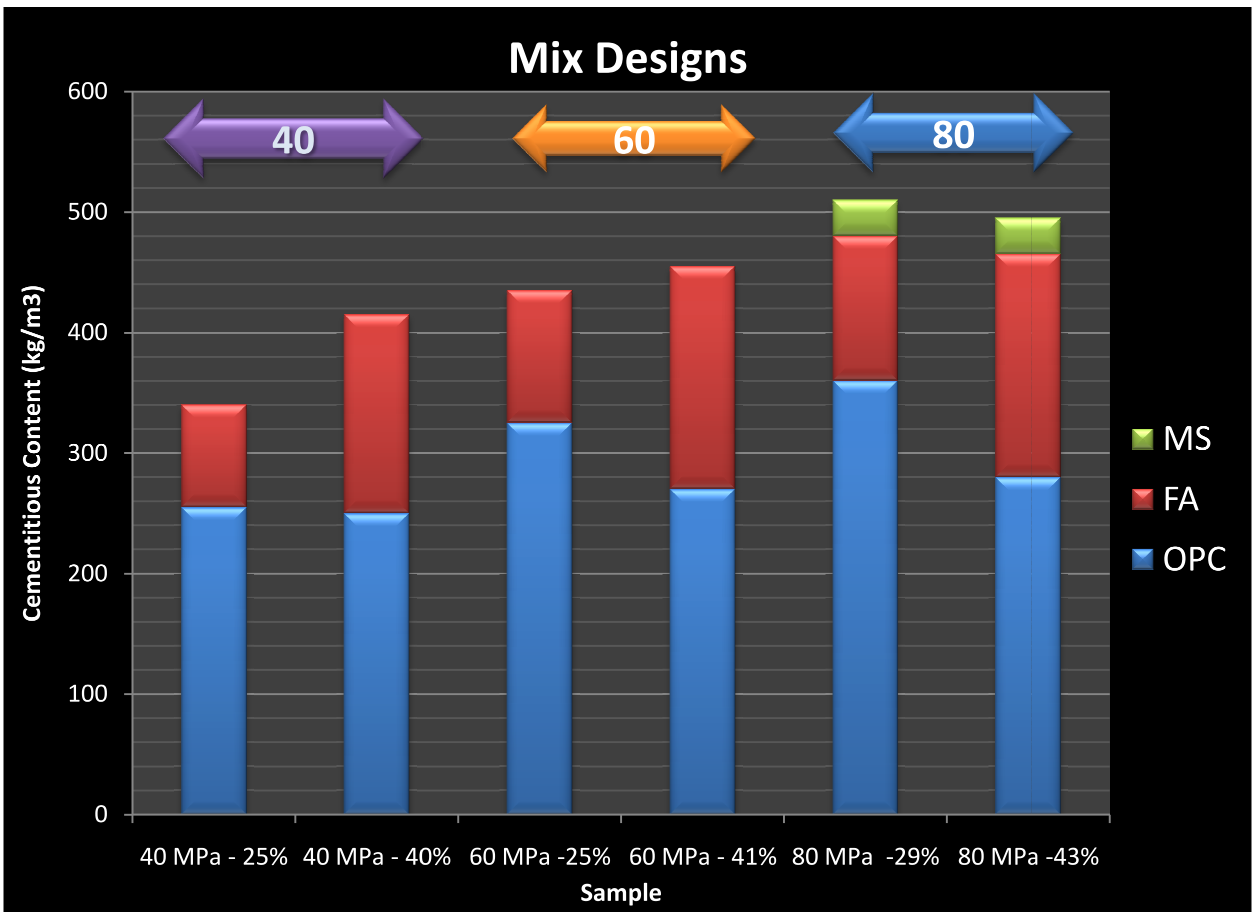
The designs as mixed varied slightly from what was initially proposed and in all cases the water content and/or cementitious content differed between similarly designed specimens. This resulted in difficulty comparing samples directly and may explain some of the results which differed from what would otherwise have been expected. For instance, it was found that the 40 MPa 25% FA concrete (EMD-01) had a significantly higher water to cement ratio when compared to the other mixes and this is demonstrated in some of the results.

Cement and aggregates were supplied locally, while fly ash was coming from India. Micro Silica was also used in high strength samples to increase performance in a manner that is already standard in the UAE.

Table 1 - Concrete mix designs used

Sample	Target Strength (MPa)	SCM content (%)	OPC (kg/m3)	FA (kg/m3)	MS (kg/m3)	Water (kg/m3)	CM	W/CM
EMD-01	40	25	255	85	0	166	340	49%
EMD-04	40	40	250	165	0	152	415	37%
EMD-02	60	25	325	110	0	148	435	34%
EMD-05	60	41	270	185	0	138	455	30%
EMD-03	80	29	360	120	30	153	510	30%
EMD-06	80	43	280	185	30	146	495	29%

Figure 1 - Cementitious contents



Fresh Concrete Properties

Slump

There were some initial issues with slump retention during the mixing of the concrete samples. As a result EMD-02 had to be mixed twice as the first batch still collapsing after 90 minutes. However, upon remixing slump was retained on all samples.

Changes in superplasticizer volumes may explain the difficulties in slump retention though it is unclear whether difficulties with slump retention were due to the originally specified volumes or due to changes made during mixing.

Table 2 - Slump Retention tests

Sample	Initial Slump (mm)	Initial Slump Form	30 min Slump (mm)	30 min Slump Form	60 min Slump (mm)	60 min Slump Form	90 min Slump (mm)	90 min Slump Form
EMD-01	210	Shear	160	True	140	True	130	True
EMD-04	> 250	Collapse	230	Shear	200	True	160	True
EMD-02	> 250	Collapse	> 250	Collapse	> 250	Shear	230	True
EMD-05	> 250	Collapse	> 250	Collapse	> 250	Collapse	230	Shear
EMD-03	> 250	Collapse	> 250	Collapse	230	True	220	True
EMD-06	> 250	Collapse	> 250	Collapse	> 250	Collapse	220	Shear

Bleeding and Air Content

No bleeding was observed on the fly ash concretes as expected. Air contents were tested to BS EN 12350: Part 7 (2000) and results are tabulated in Table 3 below.

Table 3 – Bleeding and Air Content

Sample	Bleeding (%)	Air Content (%)
EMD-01	0	1.3
EMD-04	0	1.2
EMD-02	0	1.1
EMD-05	0	1.0
EMD-03	0	0.9
EMD-06	0	1.1

Durability Testing

Electrical Resistance to Chloride Ion Penetration

The Rapid Chloride Penetration (RCP) Tests (done to ASTM C1202) was used to give an indication of the resistance to corrosion that the fly ash concretes would have. ASTM C1202 categorizes the results based on the total charge passed through the concrete after a 6 hour timeframe. This leads to a designation as High, Moderate, Low, very low or negligible as shown in Table 4 below.

Table 4 - RCP Test Result designations

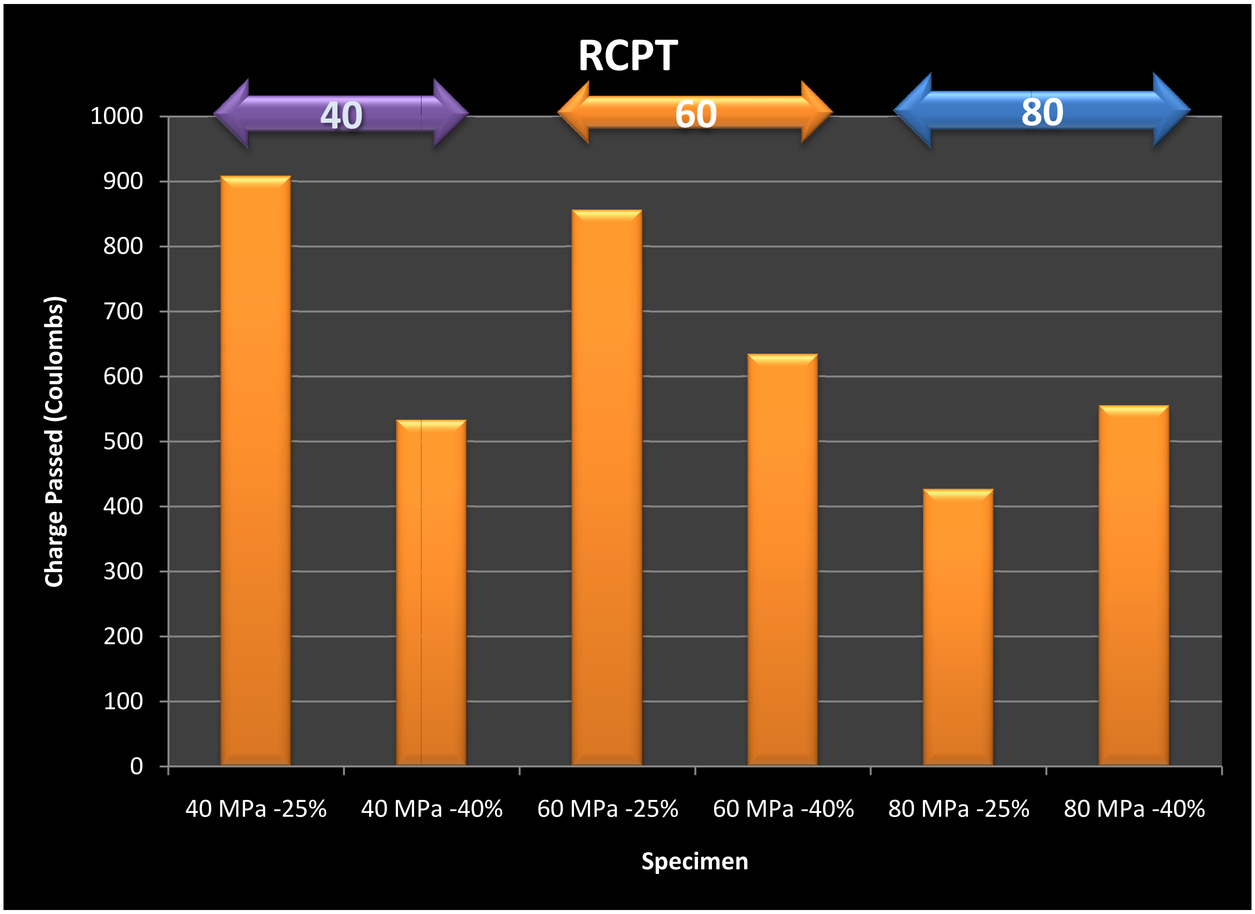
Charge Passed	Designation
> 4000	High
2000 – 4000	Moderate
1000 – 2000	Low
100 – 1000	Very Low
< 100	Negligible

All mixes were categorized as “Very Low” based on their RCP test results implying a high resistance to corrosion. Low and medium strength samples appeared to increase in their resistance to chloride penetration with increasing fly ash contents whereas the high strength samples displayed the opposite results, though all samples were still classified in the “Very Low” category.

Table 5 – Results of Rapid Chloride Penetration Tests

Sample	Charge passed (Coulombs)	Class
EMD-01	908	Very Low
EMD-04	533	Very Low
EMD-02	856	Very Low
EMD-05	634	Very Low
EMD-03	426	Very Low
EMD-06	555	Very Low

Figure 2 - Rapid Chloride Penetration Results



Absorption and Depth of Water Penetration

Absorption and Depth of Water Penetration tests are further indications of the durability of concrete. Water which is able to penetrate deep into concrete provides a pathway for various potentially damaging ions which may oxidize the rebar and lead to strength loss. Typically concrete with low porosity, few and small cracks and a low water-to-cement ratios tend to display low water penetration and absorption rates.

Water Penetration tests showed a general trend of decreasing water penetration depth with increasing fly ash concretes, though testing did not show this conclusively. High strength samples showed results that were opposite of that which was expected. Low absorption values were found for all concrete samples with similar trends witnessed as in the other tests results for the low, medium and high strength samples.

Table 6- Results of Absorption and Depth of Water Penetration Tests

Sample	Absorption (%)	Water Penetration (mm)
EMD-01	1.8	6
EMD-04	1.2	3
EMD-02	1.3	4
EMD-05	1.0	4
EMD-03	1.2	3
EMD-06	1.1	4

Strength Testing

Compressive Strength Tests

Compressive strength tests were carried out over a 56 day period to determine the rate of strength development of the fly ash mixtures. The goal in designing these mixtures was to have them meet 40, 60 and 80 MPa strengths at 28 days age. Early age strength was measured at either one or two days age and further tests were carried out at 7, 28 and 56 day ages.

All mixes showed good late age strength development, which is typical of fly ash concretes, and target strengths were achieved in the low and medium strength concrete mixes while one of the high strength samples (EMD-03) met this criterion at 56 days. The results were varied due to the various cementitious contents in each cement mix and it should be noted that both medium strength mixes preformed better than the high strength mix with 43% replacement in strength gain despite a lower cementitious content. In fact, the three strongest samples at 56 days were all converging (or exceeding) 80 MPa at 56 days. In Sample EMD-05, the 60 MPa sample with 41% fly ash also appears to have been gaining strength at a higher rate than the strongest sample. If tests had been conducted at 90 days or 365 days EMD-05 may in fact have been stronger should the rates of strength gain have between the two samples remained proportional.

Table 7 - Results of Compressive Strength Testing

Sample	1 Day Strength	2 Day Strength	7 Day Strength	28 Day Strength	56 Day Strength
EMD-01	9.0	-	29.5	45.0	51.8
EMD-04	9.5	-	34.5	53.5	63.7
EMD-02	-	28.5	48.5	66.8	73.7
EMD-05	-	19.0	44.2	68.5	77.8
EMD-03	-	30.2	54.8	72.2	83.5
EMD-06	-	21.3	44.3	64.3	71.5

Figure 3 - 40 MPa compressive Strength Development

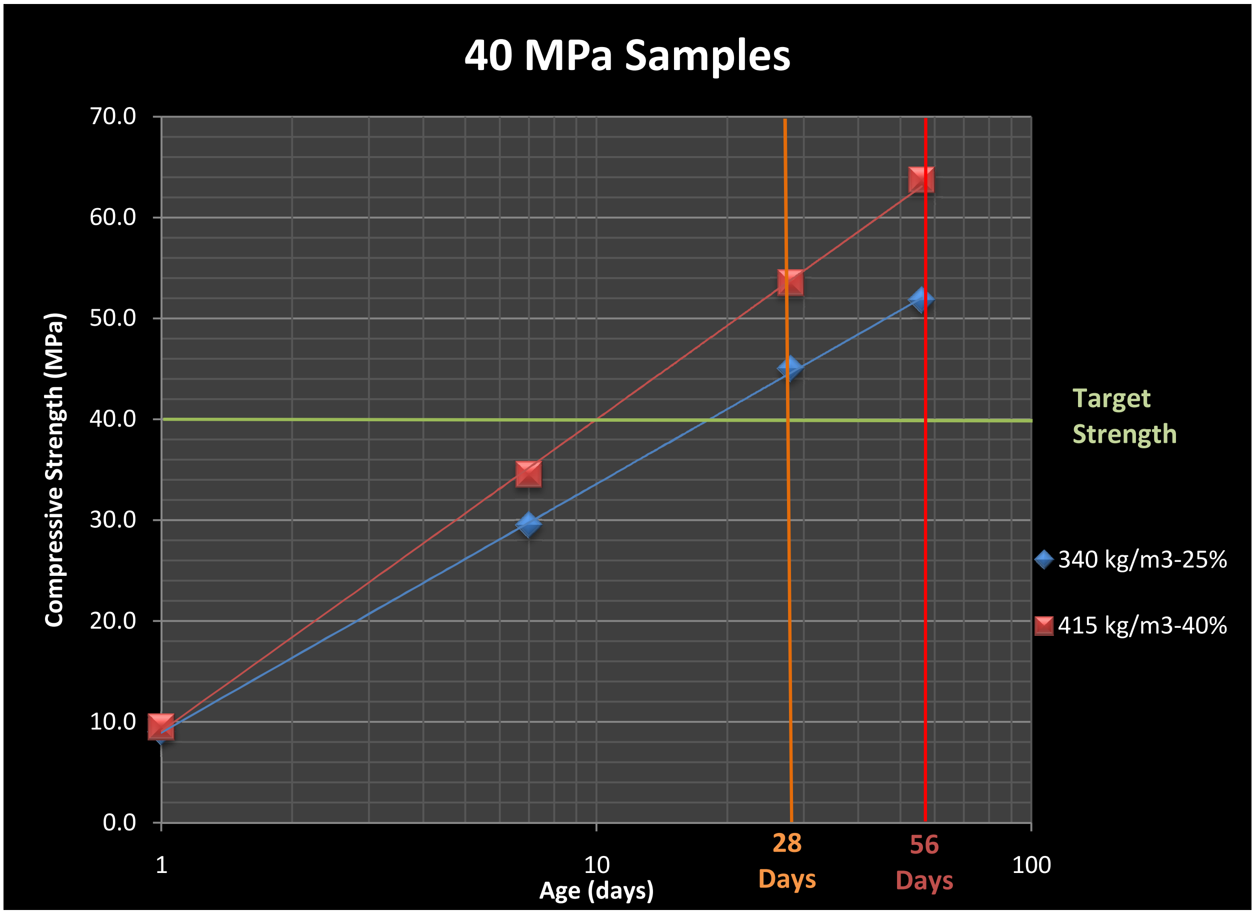


Figure 4 - 60 MPa Compressive Strength Development

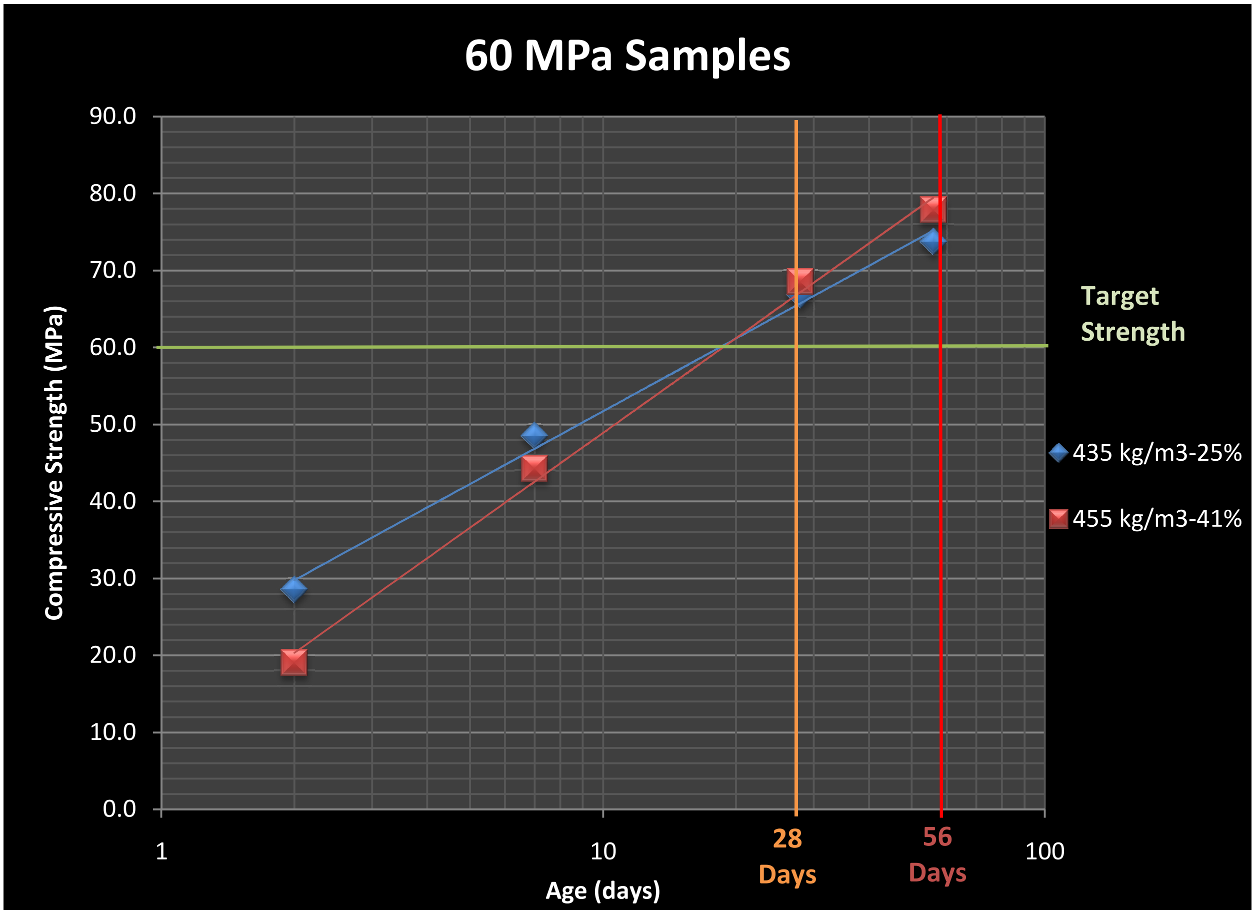


Figure 5 - 80 MPa Compressive Strength Development

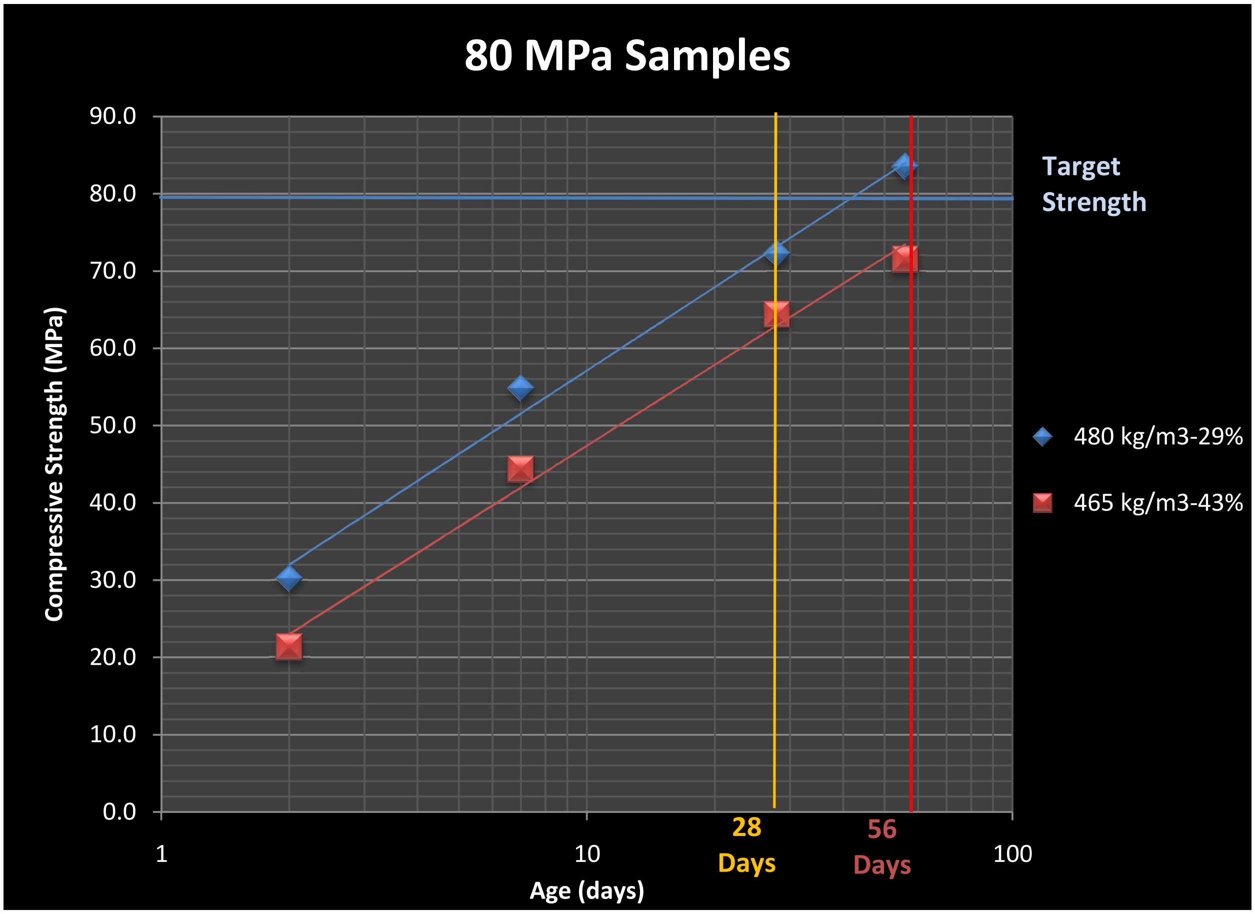
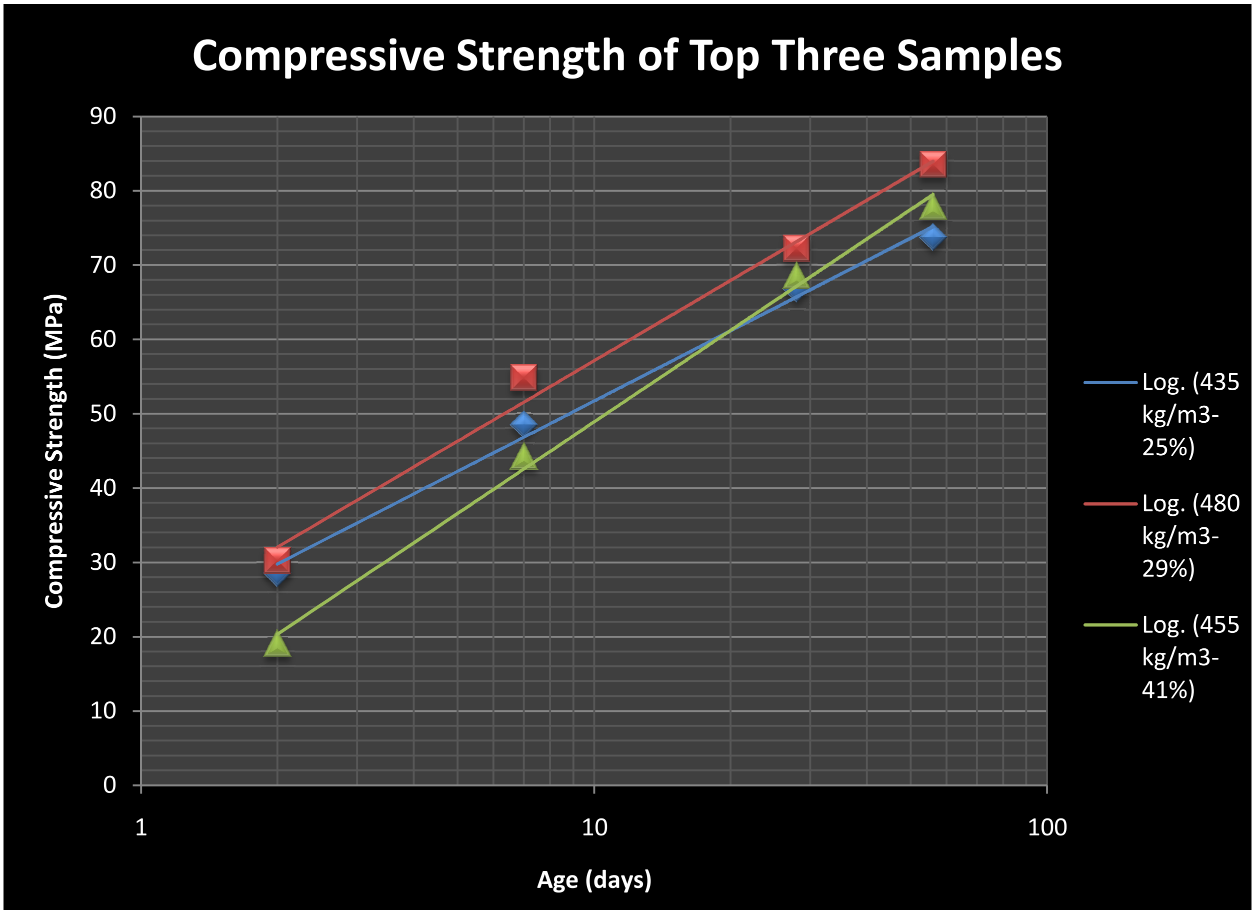


Figure 6 - Compressive Strength of Top three samples



Flexural Strength Tests

Tensile strength tests were carried out according to BS 1881 125: 1986 (AMD 6107: 1986) and the results are tabulated below. The results do not show any trend, positive or negative, in the addition of fly ash with regard to fly ash contents however the varying mix parameters may be the cause.

Table 8 - Flexural Strength Results

Sample	56 Day Strength (MPa)
EMD-01	6.1
EMD-04	6.5
EMD-02	7.8
EMD-05	7.1
EMD-03	7.1
EMD-06	7.1

Conclusion

All samples are considered good quality concrete as judged by durability criteria such as chloride ion penetration, water penetration and absorption. Target strengths were reached in all low and medium samples while high strength samples demonstrated varied results.

Based on these results it appears there is ample room for the integration of high volume fly ash concretes in the Emeriti construction environment and this could both lower CO_2 emissions and longer building life.