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POTENTIAL USE OF CARBIDE LIME WASTE AS AN ALTERNATIVE MATERIAL TO CONVENTIONAL HYDRATED LIME OF CEMENT-LIME MORTARS

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ABSTRACT

The present study aimed at the possibility of using the carbide lime waste as an alternative material to the conventional lime used for cement-lime mortar. The waste is a by-product obtained in the generation of acetylene from calcium carbide. Physical and chemical properties of the wastes were studied. Two cement-lime-sand mix proportions containing carbide lime waste were compared with the same mix proportions containing conventional lime along with a control mix without lime. Specimens were tested for strength properties in axial compression, splitting tensile, flexural along with shrinkage testing. Results of these investigations have shown that the carbide lime waste can be readily used for masonry cement mortar work.

INTRODUCTION

Growing industrialization in the Gulf countries has resulted in an increase in industrial output and consequent accumulation of unmanageable industrial waste. The diversified development projects and industrialization, in conjuction with rapid urbanization, are vigorously embarked upon to improve the standard of living. As a result, the major problem is environmental pollution by the increasing generation of domestic and industrial waste.

The utilization of industrial waste as a construction material has been the subject of extensive research. Wastes such as blast furnace slag, condensed silica fume, pulverized-fuel ash, sewage sludge, glass, and even rice husks have been successfully used in one way or another as a construction material (1-3). The successful utilization of a waste material depends on its use being economically competitive with the alternative natural material.

The increasing generation of domestic and industrial waste is highly evident in the state of Bahrain due to the small size of the island and lack of proper disposal facilities. The waste causes a significant environmental problem in the island, especially at adverse climatic conditions where the material becomes airborne. The total area of Bahrain is only 693.15 km^2 and the population density is 705 per square kilometer (4).

The amount of domestic waste generated jumped from 490 tonnes per day in 1982 to 590 tonnes in 1986. The only disposal method employed is landfilling, which consumes relatively large areas of land (5). The total amount of industrial waste generated is estimated to be more than 60,000 tonnes annually, which is partly disposed of in an industrial landfill site, and the rest is stockpiled on site (5, 6).

This problem of waste disposal will be more intensified as the quantity of wastes to be disposed increases, and the availability of environmentally-suitable landfill sites becomes a major problem.

This study presents the results of an investigation on the use of carbide lime waste as a replacement to the conventional hydrated lime used in cement-lime mortar work.

MATERIALS AND METHODS

Carbide lime is a by-product obtained in the generation of acetylene from calcium carbide. The by-product is referred to as lime hydrate, carbide lime sludge, and other such designations.

In Bahrain, there are two acetylene manufacturing plants generating about 5000 tonnes of the carbide lime waste annually. It is either stored in pits on the site or transported to a sewage treatment plant or dumped in desert areas and landfilled. The carbide lime has a greyish color and is extremely fine in particle size. Physical and chemical properties of the by-product samples were analyzed in the laboratory. The waste samples were obtained from single batches and stored in dry airtight containers, as appropriate, until use.

Sieve analysis was carried out on a representative sample, along with conventional hydrated lime and washed marine sand used in Bahrain. The sieve analysis was carried out according to British standard BS 812 (7). Grading of the marine sand was within Zone F of the British standard BS 882 (8).

Physical and chemical properties of the carbide lime were determined by using standard methods. The parameters analyzed were specific gravity, loss on ignition, silica, alumina, iron, calcium, magnesium, chloride, carbon and sulfate. The analysis of the chemical parameters was carried out according to British standard BS 6463 (9).

For the mortar part of this investigation, three mix ratios were used having five mortar mixes containing ordinary Portland cement, carbide lime, conventional hydrated lime, washed marine sand and water.

The mix ratios used were 1 : ½ : 4½ and 1 : 1: 6 along with a 1 : 0 : 3 control ratio. All mix ratios were based on volume proportions of cement to carbide lime or conventional hydrated lime to sand. The five mortar mixes chosen were, namely, 1 : 0 : 3 (control - no lime), 1 : ½ : 4½ (carbide lime), 1 : ½ : 4½ (conventional hydrated lime), 1 : 1 : 6 (carbide lime), and 1 : 1 : 6 (conventional hydrated lime). The cement-lime to sand ratio was 1 : 3 for all mixes. Table 1 shows the five mortar mixes according to BS 5628 (10). The cement and marine sand used complied with BS 882 (8) and BS 12 (11) respectively. The normal consistency of mortar mixes was maintained to yield a flow of 110± 5 percent in accordance with ASTM C-185 (12). After being removed from their moulds the specimens were immersed in water for curing at a temperature of 20°C until testing after various ageing times. However, the shrinkage specimens were removed from water after 2 to 3 days of casting and placed in control air storage of 20°C until testing (3, 7 and 28 days). The total number of mortar specimens cast was as follows: 45 compression cubes, each 50 × 50 × 50 mm, 30 splitting tensile cylinders, each 90 mm high and 90 mm in diameter, 30 flexural prisms, each 40 × 40 × 160 mm, and 45 shrinkage prisms, each 50 × 50 × 200 mm. The mortar specimens were tested for compressive strength, splitting tensile strength, flexural strength and drying shrinkage at 3, 7 and 28 days. The test results were based on the average of two mortar specimens for splitting tensile and flexural strength tests, and three mortar specimens for compressive strength and drying shrinkage tests.

Table 1
Mortar Mix Proportions

Type of mix and designation	Mortar proportions by volume			
	OPC Cement	Carbide Lime Waste	Conventional Hydrated Lime	Sand
Mix Control	1	0	0	3
Mix I	1	½	—	4½
Mix II	1	1	—	6
Mix III	1	—	½	4½
Mix IV	1	—	1	6

RESULTS AND DISCUSSIONS

The gradation and specific gravity of sand, carbide lime waste and conventional hydrated lime are shown in Table 2. It is clear that the carbide lime waste is exremely fine in size having a low specific gravity of 2.18 when compared with conventional hydrated lime and marine sand specific gravities of 2.64 and 2.58, respectively. All the particles of carbide lime waste are finer than 0.150 mm, and 67% of it passed through the 0.075 mm sieve, whereas the particles of conventional hydrated lime are finer than 0.075 mm, and 98% of it passed through the 0.063 mm sieve.

Table 2
Gradation and Specific Gravity of Mineral Aggregates

Sieve size	Marine Sand	Carbide Lime Waste	Conventional Hydrated Lime
5 mm	100	—	—
2.36 mm	98	—	—
1.18 mm	91	—	—
0.600 mm	73	—	—
0.300 mm	51	—	—
0.150 mm	18	100	—
0.075 mm	2	97	100
0.063 mm	—	—	98
Specific Gravity	2.58	2.18	2.64

The chemical composition of carbide lime waste is given in Table 3. The table shows the waste is a calcium-based lime, since it contains 65.05% by weight of calcium oxide, and it is very low on magnesium (only 0.97%). All other contaminants are relatively low. The level of chloride is found to be 0.02%, which is far below the limits for fine aggregate used in cement mortar, according to Bahrain specification of 0.10%. However, the concentration of sulphates is found to be 0.64% which is slightly higher than the maximum permitted limit of 0.40% as SO_3 of the Bahrain specification for the fine aggregate used in cement mortar (13).

The properties of mortar mixes were examined, as shown in Table 4. It is obvious from the table that the water-cement ratios of various mortar mixes have increased slightly when carbide lime and conventional lime were used. The increase in water content is mainly influenced by the increased percentage of carbide lime and conventional lime used (extreme fineness and irregular particle shape) and the total sand content. Quite clearly, the water-cement ratios of carbide lime and conventional lime mixes are more or less the same having water-cement ratios ranging from 1.1 to 1.2 and 1.4 to 1.6 for mix I and mix III and mix II and IV, respectively, as shown in Table 4. This concludes that the carbide lime mixes require the same water content as for the conventional hydrated lime.

Table 3
Chemical Analysis of the Carbide Lime Waste

Parameter	Weight percentage
Loss in ignition	27.92
Silica, SiO_2	<0.10
Alumina, Al_2O_3	<1.22
Ferric Oxide, Fe_2O_3	0.02
Calcium Oxide, CaO	65.05
Magnesium Oxide, MgO	0.97
Chloride, Cl	<0.02
Carbon, C	1.30
Sulphur, SO_3	0.64

The fresh density values for lime-mortar mixes shows no significant difference with control mix (only 1-5% variation) having a percentage of 1.7 between the carbide lime and conventional lime mixes. Thus, it can be concluded that utilization of carbide lime waste in cement mortar does not effect the density of mortar.

In comparing the compressive strength values of carbide lime, conventional lime and control cement mortar, the effects of using carbide lime show a general decrease in strength as the amount of carbide lime increases. As shown in Fig. 1 and Table 4, the 28-day compressive strength for mortar mix 1 : ½ : 4½ was 10.34 N/mm^2 and 12.10 N/mm^2 for carbide lime and conventional lime mortars, respectively, which indicates a decrease in compressive strength of 14.6%, while the 28-day compressive strength mortar mix 1 : 1 : 6 was 4.33 N/mm^2 and 7.45 N/mm^2 for carbide lime and conventional lime mortars, respectively, with a decrease in compressive strength of 41.9%. However, compressive strength results of carbide lime comply with the requirement for lime mortar mixes of BS 5628 (10) as shown in Table 4. The 28-day compressive strength values of carbide lime mixes

Table 4
Properties of Cement-Lime Mixes

Mortar mix proportion and designation (C:L:S)*	Type of lime used	Flow (Percent)	W-C Ratio	Fresh mortar density (Kg/m³)	Cube compressive strength at 28 days (N/mm²)			
					Control-no lime	Carbide lime waste	Conventional hydrated lime	BS 5628 requirement for mortar**
1 : 0 : 3 Mix Control	No-lime	114	0.8	2119	25.20	—	—	16.00
1 : ½ : 4½ Mix I	Carbide lime waste	112	1.2	2096	—	10.34	—	6.50
1 : 1 : 6 Mix II	Carbide lime waste	112	1.6	2049	—	4.33	—	3.60
1 : ½ : 4½ Mix III	Conventional hydrated lime	105	1.1	2063	—	—	12.10	6.50
1 : 1 : 6 Mix IV	Conventional hydrated lime	106	1.4	2014	—	—	7.45	3.60

* C= cement, L = lime, S = sand.

** Preliminary - laboratory test result requirements for mortar mixes (10).

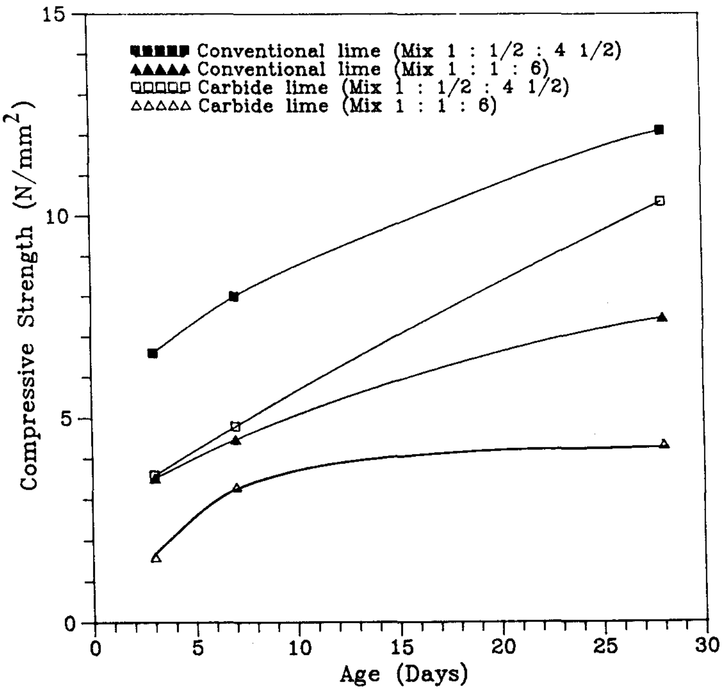

Fig. 1: Compressive strength development of conventional and carbide lime mortar mixes

were 37.1% and 16.9% higher than the BS 5628 compressive strength requirements for mortar mix 1 : ½ : 4½ and mortar mix 1 : 1 : 6, respectively. Hence, the strength of carbide lime-cement mortar is adequate for general masonry work.

Fig. 2 shows the development of cylinder splitting tensile strength with time. It is obvious that the carbide lime mixes have a lower splitting tensile strength than conventional lime mixes. The 28-day strength for mix 1 : ½ : 4½ was 0.7 N/mm^2 and 1.03 N/mm^2 for carbide lime and conventional lime mortars, respectively, which indicates a decrease in splitting tensile strength of 32.0%. While the 28-day strength for mix 1 : 1 : 6 was 0.52 N/mm^2 and 0.59 N/mm^2 for carbide lime conventional lime mortars, respectively, which indicates a decrease in splitting tensile strength of 11.9%. The average splitting tensile strength for carbide lime mixes and conventional lime mixes of different mix proportions is found to be 7.7% and 10.3% of the compressive strength, respectively.

The development of flexural strength with time for conventional and carbide lime mixes is illustrated in Fig. 3. Test results indicate that the first week flexural strength of conventional lime mixes is slightly higher than carbide lime mixes with a

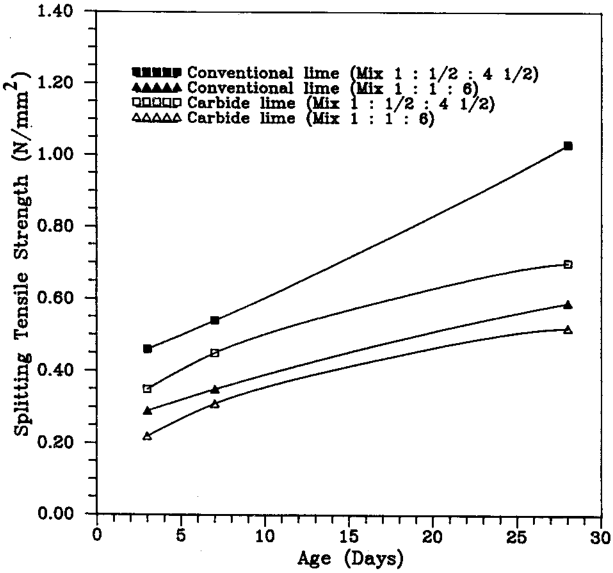

Fig. 2: Splitting tensile strength development of conventional and carbide lime mortar mixes

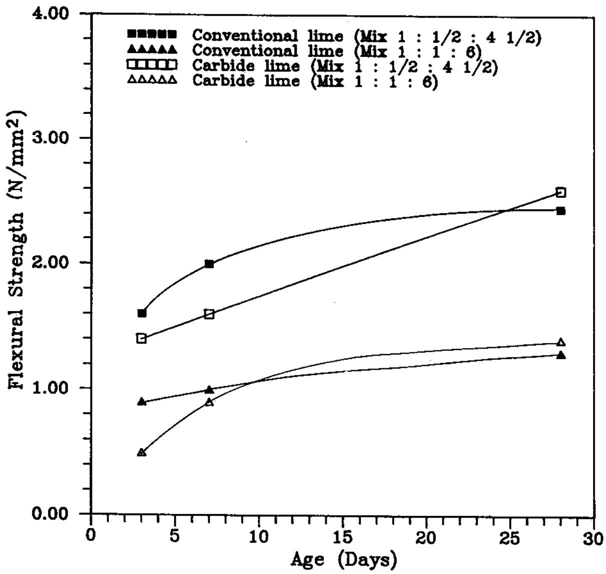

Fig. 3: Flexural strength development of conventional and carbide lime mortar mixes

maximum strength variation of 0.4 N/mm^2, whereas, the 28-day flexural strength of both conventional and carbide lime mixes is more or less the same, having flexural strength of conventional lime mix 5.8% and 7.1% lower than flexural strength of carbide lime mix for mix proportions of 1 : ½ : 4½ and 1 : 1 : 6, respectively. Therefore, it can be concluded that the use of carbide lime waste as a replacement to conventional lime has no significant difference in flexural strength.

Fig. 4 presents the 28-day shrinkage relationship between conventional and carbide lime mixes. It is interesting to note that the carbide limes mixes exhibit lower shrinkage values when compared with conventional lime mixes shrinkage values in spite of the slightly higher water-cement ratios of carbide lime mixes. For mix proportion of 1 : ½ : 4½, the 28-day shrinkage values of carbide lime and conventional lime were 0.015% and 0.021%, respectively, which indicates that the conventional lime mix exhibits 28.6% higher shrinkage than carbide lime mix. Furthermore, when mix proportion of 1 : 1 : 6 was used, the 28-day shrinkage of conventional lime mix was 41.4% higher than the shrinkage of carbide lime mix given shrinkage values of 0.017% and 0.029% for carbide lime and conventional lime mixes, respectively. Thus, it can be said that the use of carbide lime as an alternative to conventional lime is beneficial as carbide lime can considerably reduce shrinkage when compared with conventional lime.

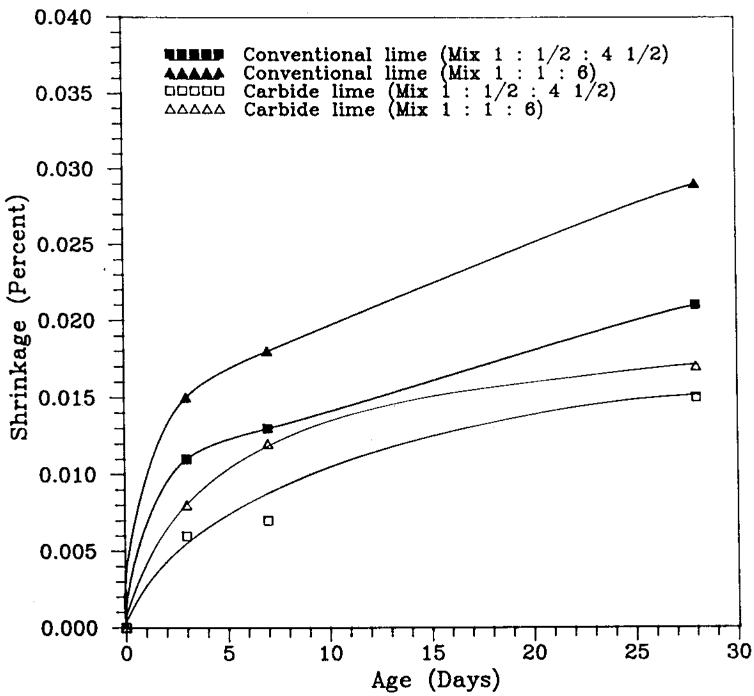

Fig. 4: Shrinkage development of conventional and carbide lime mortar mixes

CONCLUSIONS

On the basis of the results described before, the following conclusions can be drawn:

1. Both carbide lime and conventional lime mixes require the same water content and water-cement ratio to achieve the same workability.
2. No significant difference in mortar densities were observed for various mortar mixes (control, carbide lime and conventional lime mixes).
3. The reduction of compressive strength values achieved by using carbide lime comply with British standard BS 5628 for mortar lime mixes, and the strength is adequate for general masonry work.
4. The splitting tensile strength of mortar lime mixes reduces with the use of carbide lime. However, no significant difference in flexural strength was observed between the carbide and conventional lime mixes.
5. The shrinkage can considerably be reduced when carbide lime is used for cement lime mixes.
6. Carbide lime waste could be utilized as a replacement to conventional hydrated lime used for cement-lime mixes.

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