UNIVERSITY OF MAURITIUS

GAMMA-CIVIC

Use of coral sand and crushed basalt sand for mortars for plastering and rendering in the construction industry.

Ravi Gutty

March 2001

UNIVERSITY OF MAURITIUS

GAMMA-CIVIC

M.R.C. Private Sector Collaborative Research Grant Scheme

Use of coral sand and crushed basalt sand for mortars for plastering and rendering in the construction industry.

FINAL REPORT

March 2001

Executive Summary

The purpose of this research project was to investigate the suitability of crushed basalt sand and marine dredged coral sand as an alternative to lagoon coral sand for plastering and rendering purposes. To achieve this objective, investigations were carried out in three stages.

The first stage consisted of assessing and comparing the properties of the two sands under investigation with lagoon coral sand, the sand traditionally used in the construction industry for plastering and rendering.
The second stage was to incorporate the different sands in mortar and to develop optimum mixes for each sand.
The final stage was then to investigate the shrinkage properties of the optimum mixes and to simulate internal plastering and external rendering as done on sites so as to compare the characteristics of each sand when used in plaster or render.

It was found that optimum mixes with the two sands were not entirely satisfactory, though they satisfied the relevant British Standard Specifications, without the use of appropriate admixtures to improve the properties of the mortars incorporating the sands.

The optimum mix (with admixtures) with the dredged coral sand proved to be more interesting than that with the crushed basalt sand in that it has a lower percentage of cement, hence is more economical and has lesser risk of shrinkage problems.
These two advantages were confirmed by a cost study for the production of mortar with the two sands and by shrinkage tests carried out in laboratory conditions and verified by actual site simulation of plastering and rendering.
Savings in cement can however be achieved with optimum mixes of both sands as compared to traditional lagoon coral sand.

The crushed basalt sand can be made suitable for plastering and rendering purposes through the use of admixtures to improve its properties in mortar.

The dredged coral sand can be used in mortars for plastering and rendering satisfactorily though the use of admixtures is recommended.

Although both sands are suitable, the dredged coral sand would however be a preferred alternative to lagoon coral sand because it embodies, to a greater extent, the properties of the latter, gives mortars better performance in terms of workability and finish, and entails greater savings in cement.

Acknowledgement

The contribution of the members of the Research Team towards the realisation of this Project is gratefully acknowledged.

Members of the Research Team:

Mr. D. Singh	Principal Investigator	Gamma-Civic Ltd.
Dr. B.K. Baguant	Research Institution Investigator	University of Mauritius
Mr. R. Gutty	Research Officer	Gamma-Civic Ltd.
Mr. A. Chung	Project Co-ordinator	ReadyMix Concrete Ltd.
Mr. N. Pittea	Laboratory Supervisor	Gamma-Civic Ltd.

We acknowledge the participation of Dr. A. Suddhoo, Executive Director and Mr. K. Heeramun, Manager Research Technology and Development, both of M.R.C. in the funding of the Project.

I would also like to thank Malini and Rajshree of M.R.G.C. Construction for their help in typing this report.

Ravi Gutty

12 March 2001.

Table of contents

1. Background of the Project

1.1 Introduction

Cement mortar comprises Portland cement, water and sand. Sand is an important constituent of mortar. It gives body to the mortar, reduces shrinkage and the fact that it occupies about 70 to 80 per cent of its volume, it affects considerably the cost of the latter.

The selection of a suitable sand for the production of mortar is therefore of prime importance and is greatly influenced by the cost incurred in obtaining the sand.

Sand used in construction can be of different origins. For Mauritius the two types of sand readily available are coral and basalt sands, which have two distinct origins.
Due to the nature of coral sand, not much processing is required before using the material for construction purposes when compared to basalt sand. In fact, it needs to be washed and sieved to remove salinity and unwanted fine particles such as clay and silt.
However, for basalt sand a series of mechanical processes must be performed before the raw material is converted into sand. This makes the coral sand more advantageous in terms of readiness for use.

1.11 Lagoon coral sand: a rapidly-depleting non-renewable natural resource

Facts:

- Mauritius barrier reef: 150 km long (inclusive of interruptions at 3 points of about 30 km) x 10-15 m wide
- 1 sq.m of coral produces 4 to 5 grams of coral sand per annum
- Annual production of coral sand in Mauritius lagoon approximates 7.2 tons, at most *(Re: Baguant & François, 1991)*
  Average annual extraction of sand from lagoon approximates 500,000 tons per *annum* *(Re: Australian Water and Coastal Studies, 1993)*
- Extraction being carried out in waters shallower than 1.5 m subjects the bottom material to wave and current induced movement, which further restricts the movement of replenishment material on to the beach
- With a renewal rate of this natural resource lagging far behind consumption / extraction rate, it is crucial that measures be taken to safeguard our marine ecosystem.
  Especially with an economy relying heavily on the tourism sector, Mauritius cannot afford to lose an asset as important as its lagoon.

  Source: 1. Institutional collaboration to promote the use of replacement construction material as an alternative to coral sand depletion, B.K. Baguant & C.P. François, July 1991
  2. AWACS report - Mauritius sand dredging study, R.J. Cox, J.P. Hudson, N. Sooreedoo, Nov. 1993.

1.12 Negative impact of sand extraction on lagoon

Two major marine ecosystems threatened by sand extraction:

1. Seagrass beds which:

- Trap and stabilise sediments
- Act as habitat, feeding and nursery grounds for reef fishes and invertebrates
- Dampen wave action
- Help in recycling of nutrients.

2. Coral reefs which:

- Act as barrier against oceanic waves and dissipate wave energy
- Act as habitat, feeding and nursery grounds for marine organisms
- Help in formation of sand and beaches.

Turbid plumes of sediment rising from extraction process contribute to:

- Reducing illumination: photosynthesis cannot take place and therefore seagrass die or become poor in quality
- Destruction of nursery and feeding grounds for reef fishes and invertebrates
- Destabilisation of lagoon bed, and hence changes in patterns of back reef sedimentation, movement of sand, covering of coral / seagrass with sediment
- Interference with feeding and respiration which lead to stress, smothering and even death of corals
- Deterioration of algae which results in degradation of oxygen content in environment, and hence mortality of fish and marine organisms.

1.2 Need for substitution of lagoon coral sand

Due to the prime importance of sand in the construction industry, the growth of the latter is inevitably causing an increase in the demand of coral sand.
However, extensive use of coral sand implies pronounced exploitation of the coastal and marine environment of the country.

When the rate at which coral sand is being used and its estimated rate of replenishment are compared, it can be said that coral sand is a non-renewable resource. This pronounced exploitation of lagoons is therefore having a direct negative effect on the marine ecology.
Moreover, uncontrolled quarrying of sand in the lagoon would destroy the beauty of the beaches all around the island and hinder the flourishing of the tourist industry.

Because of all these anticipated problems, authorities concerned have enforced laws to prevent excessive exploitation of lagoon coral sand during the past few years.
Government has recently announced its intention of banning completely lagoon sand extraction in the near future. These measures have been one of the factors that have contributed in increasing the cost of implementing building and civil engineering works.

However, since it is important for the construction industry to grow, to maintain economic growth of the country, it is vital that substitutes for coral sand be found.

The desired properties that the substitutes should have for them to be accepted are:

1. Availability
2. Economic
3. Similar properties to coral sand.

2. Objectives of the Project

This project principally aims at assessing the suitability, from a technical and performance point of view, of two possible substitutes to counter for the rapid depletion of coral sand:

- A marine-dredged fine coral sand
- A 0/5 mm crushed basalt sand (sieved)

in different mortar proportions for internal plastering and external rendering purposes.

In parallel, two other objectives are:

- To bring down the prevailing costs of currently produced cement sand mortars (with or without admixtures) for the benefit of end users
- To ensure the development of crack free plaster and render in the local construction industry by limiting excessive proportion of cement in mixes.

3. Approach and Methodology of work

The aim of this project is to assess the suitability of the 0/5 basalt sand and of the dredged coral sand for plastering and rendering purposes. To achieve this objective, the physical properties of the two sands were firstly evaluated and compared with those of traditional lagoon coral sand. Then the behaviour of the sands in mortar was studied.
The properties of mortars that were investigated were consistency and flow, water retentivity, air content, plastic density, compressive strengths, and shrinkage.

The work programme is detailed in Annex 1.
The experimental work basically consisted of a study of the properties investigated with changes in the mix proportions of one component at a time.

For all the tests on mortars, with and without admixtures, the workability was kept constant and the water demand that would give the desirable workability, for each mortar mix tested, was varied.
For tests on mortars with admixtures the percentage of retarder was kept constant (to achieve 36 hours retarding) and the percentage of air was varied, with the optimum mix for each sand obtained without the use of admixtures, to determine the optimum percentage of air for each sand for the properties tested.
The different test mixes under investigation were then tested with percentages of retarder and air fixed to determine final optimum mixes (with admixtures) for the two sands.
A detailed schedule of laboratory tests carried out for tests on mortars with admixtures is presented in Annex 2.
Finally internal plastering and external rendering were also simulated, on cellular concrete blocks, with the final optimum mixes of the coral sand and the basalt sand. Their behaviour in relation to shrinkage was then assessed on the basis of observation.

Table 3 gives in sequential order the properties that were investigated on the sands and mortars together with the appropriate British Standard used.

Properties	Test method
Material characteristics	
Grading	BS 1199: 1976
Relative density	BS 812: Part 2
Water absorption	BS 812: Part 2
Bulk density	BS 812: Part 2
Percentage voids	BS 812: Part 2
Fresh characteristics of mortars	
Flow	BS 4551: 1980
Consistency	BS 4551: 1980
Water retentivity	BS 4551: 1980
Air content	BS 4551: 1980
Plastic density	BS 4551: 1980
Hardened characteristics of mortars	
Compressive strength	BS 4551: 1980
Shrinkage on prism samples	BS 1881: 1970
Shrinkage on cellular blocks	

Table 3 Tests on sand and mortar

The laboratory work spanned over a period of approximately five months. Throughout the testing period the laboratory had an estimated mean temperature of about 22°C and mean relative humidity of about 60%.

4. Presentation of the Sands studied

4.1 Crushed basalt sand

4.11 Review of previous work on 0/6 mm crushed basalt sand

The 0/6 crushed basalt sand (commonly known as "sugar size rocksand") is dark-coloured and comprises particles ranging from 0 to 6 mm. The particles are flaky and angular, when compared to coral sand with more rounded particles.

The findings of previous investigations on the properties of lagoon coral sand and 0/6 rocksand can be summarised as follows:

1. The grading curve of lagoon coral sand satisfies the grading limits specified in BS 1199: 1976 while the major part of the grading curve of 0/6 rocksand lies completely outside those limits. 0/6 rocksand consists of a high proportion of very fine and very coarse particles

2. Coral sand has a higher water absorptivity (about 3 to 5 times) than 0/6 rocksand

3. Coral sand contains a greater percentage of silt than 0/6 rocksand

4. The relative density of 0/6 rocksand is greater than that of coral sand

5. Mixes containing rocksand exhibit higher compressive strengths than those containing coral sand, for the same cement/sand ratios, do.

Because of its flaky and angular shape and of its coarser grading, "sugar size rocksand" has proved to be a difficult material to use for rendering and plastering. Being denser than coral sand, mixes with it are heavier, thus more difficult to work with.

4.12 0/5 mm crushed basalt sand

The 0/5 crushed basalt sand is obtained by crushing coarse aggregate in a mill or impact jet crusher. Its grading is different and particles are more rounded. It consists of materials ranging from 0 to 5 mm. The aim of its production was to compensate for shortage of "sugar size rocksand".

Its effectiveness in most concrete construction works has been assessed so far, except for its use for rendering and plastering purposes.
This project aims therefore at investigating the suitability of this 0/5 crushed sand for rendering and plastering.

4.2 Marine dredged coral sand

The marine dredged fine sand is in fact coral sand that has been formed due to the degradation of coral reefs from wave action. The fine nature of this sand can be explained since the aggregate has undergone more abrasion when compared to coarser lagoon coral sand due to the former being deposited further back in time.

This sand is an outer-lagoon coral sand. In line with its policy of phasing out the use of lagoon coral sand, Government allowed for a mechanical dredging project to be undertaken. This allowed for a stock of outer-lagoon coral sand to be built in view of catering for the needs of consumers upon phasing out and banning of extraction of sand from lagoons.

The fine sand was extracted from regions outside the lagoons by means of a dredging process. This type of dredging process of sand for commercial purposes is a rare activity in Mauritius. Up till now the majority of the coral sand available on the market has been extracted from the lagoons or inland deposits and is of coarser nature compared to the sand under investigation. Also, since the fine sand is a fairly new product on the market, little research has been performed up to now on the sand incorporated in mortars. Therefore, this project will provide an opportunity to gather more information on the suitability of this fine sand to be used in mortars for rendering and plastering.

4.21 Sites for winning of sand material

The intention of the mechanical dredging project carried out was to win material from within the port itself and from suitable sea bed deposits outside the lagoon. This had the advantage of dredging material required to be removed from the port approaches. This material had built up as part of the natural coastal process of sediment transport and sedimentation.

In general, a site for winning of sand material has to meet a number of criteria including:

- Availability of sufficient material of the required specification
- Located in an area of suitable water depth.

4.22 Assessment of impacts on the environment

The dredging project did not *a priori* show major potential impacts as the worst impacts on the environment might have already been caused by port-related activities.

4.221 Common environmental issues

- Changes to bathmetry / wave patterns / erosion / deposition / currents
- Impacts on marine ecology including benthic communities within the sand
- Increased turbidity / suspended solids
- Noise and dust generation
- Increased vehicle movements in the vicinity of sand treatment plant
- Visual impact of dredging ship along coast (holiday villas / hotels etc...)
- Interruption to divers during dredging
- Gaseous emissions from plant
- Visual intrusion of stockpiles
- Disturbance to diving sites.

4.222 Potential significant environmental impacts of a sand dredging project

The three components of such a project that constitute sources of impacts:

1. Dredging
2. Stockpiling
3. Processing and end-users.

Each activity has the potential to generate impacts that may have effects on the different environmental receptors of the impact areas.

- ***Impacts generated by dredging***

The most significant impact of dredging activities is associated with the generation of sediment plumes. These plumes can travel varying distances depending on the current flow patterns. The settlement of these sediments can be detrimental to marine life as they severely impair the photosynthetic ability of symbiotic algae associated with corals.
In the case of the dredging project carried out, in Port-Louis, however, there were no live corals in the vicinity of the dredging area.

Adverse effect can be experienced at marine locations such as dive sites and the shoreline on account of the disturbance caused by the dredging activities if dredging is carried out too near. In the case of the project, as the dredging activity was only a temporary one that lasted about two months, the esthetical effect was not of any real significance.

- ***Impacts of stockpiling***

The use of earthmoving equipment on the stockpiling site is a potential source of noise, which can adversely affect the amenity of residential and business areas that are located nearby. There were no residential developments nearby and therefore no significant effect in the case of the project.

Stockpiling of dredged material up to a height of 10 meters may cause visual unpleasantness. The location of the site, Fort-William (Bain Des Dames), for the project, is away from residences.

Stockpiled material may dry up and consequently constitute a significant source of air pollution as sand particles of dust are blown away by wind. The airborne particles can travel over long distances before settling down.
In the case of the project, the prevailing winds generally blow from the south-east i.e. sea-ward from the site and not land-ward.

- ***Impacts of processing and end-users***

The dredged material inevitably includes larger pieces of dead coral that have to be crushed and processed before disposal. This activity requires the use of motorised equipment, while disposal of the sand to end-users generates additional traffic on the road network. The impacts likely to be generated can be summarised as follows:

- Noise and vibrations from equipment used in processing

- A certain quantity of spoils and waste generated by the activity and the labour force

- Traffic related impacts, which may constitute the most significant ones in this category. In fact, the commercialisation of about 1 million cubic metres of sand over three years may probably result in the generation of an additional 120 - 150 one way trips daily on the road network.

In the case of the project, these impacts were restricted as residential and business areas are not located nearby and the site is situated in the vicinity of the highway network.

To sum up, the various potential environmental impacts of such a sand dredging project can be controlled and restricted by a wise choice of the dredging, stockpiling and processing sites.

4.3 Guidelines for plastering and rendering

For this project three British Standards relating to rendering and plastering were consulted:

1. BS 1199 : 1976 Building sands from natural sources
2. BS 4551 : 1980 Methods of testing mortars, screeds and plasters
3. BS 4721 : 1981 Specifications for ready-mixed building mortars.

Note on Specifications for building sands (BS 1199:1976):

The code provides grading limits for both coarse and fine sand. However in the case of the two sands being studied, only the fine grading limits were considered.

The Standard also states that: *"Sands complying with the grading requirements for sieve apertures in the range 6.3mm to 600μm but exceeding the requirements for the percentage passing 300μm, 150μm and 75μm sieves may also be considered as being satisfactory where there is evidence of acceptable performance in use".*

Therefore, the Standard also provides for the use of sands falling outside the grading requirements if it can be demonstrated that they have satisfactory performance.

5. Physical properties

5.1 Introduction

Mortar is a mixture of a binding agent, fine aggregate and water. For the purpose of this study the binding agent was Ordinary Portland Cement and the fine aggregate, the two sands. In most mortar mixes used for rendering and plastering the fine aggregate occupies around 50 to 55 % of the volume of the mix.
Thus aggregate constitutes a key part of mortars and will undoubtedly have an effect on the performance of the mixes in terms of working properties, water demand, setting time and behaviour of the finished product.
Sand particles are coated and lubricated by the cement paste to provide the flow and body needed in a plastic mortar and are cemented together as the paste hardens, providing required structural properties.
Therefore, it is important that the properties of the two sands be assessed since this helps in predicting how the mortar incorporating the sands will behave.

The physical tests performed on the sands were as follows:

1. Particle size distribution (grading)
2. Relative density
3. Water absorption
4. Plastic density
5. Void content.

5.2 Benefits of a well graded sand

As said earlier, aggregate comprises about 55% of the volume of mortar. Thus the way particles of aggregate fit together in the mix, as influenced by the grading, shape and surface texture, has an important effect on the workability and finishing characteristics of fresh mortar and consequently on the properties of hardened mortar.
Proper interlocking of particles, which dictates workability of a mix, can be achieved by proper grading of aggregate.

Good grading implies that a sample contains minimum voids. A sample of the well-graded aggregate containing minimum voids will require minimum paste to fill up the voids in the aggregate.
Minimum paste will mean less cement and less water, which, not only implies increased economy but higher strength, lower shrinkage, greater durability and better performance from the point of view of cracking resistance.

5.3 Physical properties of the two sands

5.31 The 0/5 crushed basalt sand

0/5 basalt sand that is used for rendering on site is normally sieved through a 2-mm square wire mesh and materials passing used for rendering. The purpose behind this practice is to remove coarse particles that hinder production of a workable mix.

It is also known that coarse particles give rise to plastering problems – in particular, no good finish can be achieved in the presence of the coarse particles. They tend to come to the surface under the action of the trowel or the wood float.
It is from these observations that sieving of the basalt sand was considered. The sieving operation on site is rarely 100% efficient. A 2.36-mm sieve was chosen for laboratory experiment purposes as a standard BS sieve aperture.

5.32 The dredged coral sand

No further modification was carried out on the sand in terms of washing or sieving. The sand as obtained from the stockpile had already gone through the sieving and washing process at the sand processing plant at Fort-William.
Therefore it was thought not to be practical to modify the sand because it would have represented the type of sand that is available to the local masons for rendering and plastering.

In the rest of the study, the two sands under investigation will be referred to as follows:

1. Sea dredged fine coral sand – Sand 1
2. Sieved 0/5 crushed basalt sand (0/2.36) – Sand 2

5.4 Results of physical properties

Property	Sand 1	Sand 2	Lagoon sand (typical results)
Particle size distribution – grading (mm)	0 – 3*	0 - 2.36*	0 – 4*
Relative density on oven dry basis	2.61	2.87	2.38
Relative density on saturated and surface dry basis	2.64	3.01	2.45
Bulk density on uncompacted sample (kg/m^3)	1220	1964	1137
Bulk density on compacted sample (kg/m^3)	1330	2380	1364
Void content on uncompacted sample (%)	52	30	49
Void content on compacted sample (%)	48	16	41
Water absorption (%)	2.2	4.9	3.0

Table 5.4 Results from physical tests on sands * See Grading curves-Annex 3

5.5 Discussion of results

5.51 Grading

- Sand 1

Most of the curve is within the limits set out by the British Standards. It is only the portion finer than 150 µm that is just at the upper limit.
However, as mentioned previously, the Standard has made provision for such type of sand by stating that sands that exceed 300 µm, 150 µm and 75 µm limits can still be used if proof of acceptable performance exists.

Also, the presence of a significant amount of fine materials gives an indication that the mortar mixes produced will not be harsh.
From the grading obtained, there is an indication of a high water demand of the mortar mix using the fine sand due to the presence high proportion fine material causing the formation of excess voids which will have to be filled with cement paste.

- Lagoon coral sand

The grading curve is well within the BS limits for sands.

- Sand 2

A major part of the grading curve lies outside the limits. This crushed sand has an excess of very fine particles.

However, these results do not give much information about the probable behaviour of these sands in mortar in fact. The limits set up in British Standards refer to sand in Great Britain and it is most likely that the aggregates found in Great Britain and those found in Mauritius do not have similar characteristics and hence their behaviour in mortars may be different.
Hence, the limits stated in British standards may not apply to local sands or to sands in other countries outside Great Britain.

This argument is supported by the fact that countries like South Africa, India and Australia among others, have their own standards, which are quite different from British standards. These limits were set for natural sands for which an upper limit was placed for amount of fines because of probable presence of clay and silt. Moreover, mixes with much fines require a higher water / cement ratio and this can cause greater shrinkage.

To conclude, suitable mixes might be produced with either of the two sands. However, from the point of view of workability it can be expected that better results be achieved with Sand 1 due to the finer grading. But these arguments can only be verified after actual mixes have been investigated.

5.52 Relative Density and Absorption

- Sand 1, Sand 2 & Lagoon coral sand

The relative densities obtained are typical values for such type of natural aggregate. Note that the values for Sand 1 compare better with those of the lagoon coral sand.

The absorption of 2.2% obtained for Sand 1 might be underestimated and is most likely due to the difficulties incurred in obtaining the aggregate in the saturated and surface dry condition. Still this value compares better with that of the lagoon coral sand.
The high value of 4.9% for Sand 2 can be explained by the high percentage of fines of the latter.

5.53 Bulk Density and Percentage Voids

- Sand 1, Sand 2 & Lagoon coral sand

The bulk density for Sand 1 has an average value of 1275 kg/m^3 (average of compacted and uncompacted sample), which is close to that of the lagoon sand.
Sand 2 however has a much higher average bulk density. This is easily explained by the completely different nature of the sand compared to the other two.

The void content for Sand 1 has a high average value of 50%. The high void content indicates that the particles are not densely packed together. This can be due to the fineness of the sand producing excess voids when packed together.
Consequently mortars making use of Sand 1 will have a high water demand to achieve the desirable consistency.

The low void content for Sand 2 indicates this sand will produce mortar mixes with lower water demand than Sand 1 for the same consistency, hence lower risk of shrinkage problems. However it may not be the material of choice as for rendering and plastering, workability is the governing factor.

6. Properties of Mortar using the sands

6.1 Introduction

Characteristics that are important for acceptable performance of mortars for rendering and plastering purposes are as follows:

1. Improve appearance of concrete
2. Easily workable
3. Reasonable rate of hardening to maintain speed of construction
4. Good resistance to penetration of rain
5. No cracking
6. No crazing
7. No loss of adhesion
8. Good life span.

In relation to these characteristics, properties of mortar were investigated from the fresh to the hardened state. Tests were performed in accordance with British Standards.

From the results obtained, the suitability of the sands in mortars were assessed together with predictions to how the mortars would behave before actually plastering or rendering with them on a large scale.

6.2 Need for sufficient workability

Workability can be generally defined as the ease to which a mix can be transported, placed and finished without segregation.
In practice it is difficult to measure workability as defined, what can be measured are other parameters that are related to the workability such as flow and consistency.

The consideration of workability of mortar mixes is very important for mortars in the plastic state for the simple reason that if the mix produced is not sufficiently workable all the desirable properties that the mortar is supposed to achieve will not be obtained, resulting in poor finished product.
Providing for workable mixes will reduce the voids present within the mix since air voids are easier to expel due to the ease of compaction thus resulting in a mix of higher strength and durability. When considering the workers, having a workable mix would be advantageous since masons will have to incorporate minimum effort to use the mortar mix leading to an improved productivity and workmanship of the rendering and plastering operation.

For each test mix (different cement / sand ratios or different air contents), the water / cement ratio was varied and for each water / cement ratio the corresponding properties of the mortar were recorded.

6.3 Mix proportions under investigation

Different cement / sand proportions were investigated using the two sands as shown in table 6.3.

Sand	Mortar designation	% cement by weight of dry materials	Nominal proportions by volume*
Sand 1	A	25	1:3
	B	20	1:4
	C	15	1:5-6
	D	10	1:9
Sand 2	E	25	1:3
	F	20	1:4
	G	15	1:5-6
	H	10	1:9

Table 6.3 Mix proportions of mortars under investigation *Cement:sand proportions

The mass of dry sand required for individual tests was calculated from the moisture content.

As can be seen from the table, four mixes were thus investigated for both sands. The first mixes (A, E) represent rich mixes of 25% cement content and whilst descending the table the mixes gets leaner with the leanest mixes (D, H) being of 10% cement content.
Leaner mixes were investigated since within the construction ring it is thought that a 1:3 mix is the optimum mix to be used for usual sands, which might not be the case for the two sands under study in terms of both performances and cost.

6.4 Experimental work

6.41 Procedure

In the plastic state the consistency, flow, water retentivity, air content and plastic density of the mixes were measured.

In the hardened state the compressive strength at different ages were determined. 100-mm cubes were used for the tests. Three specimens were prepared for testing at each of 7 and 28 days.
To simulate site conditions (as far as plastering and rendering are concerned), the cubes were not covered by a moist cloth for curing.

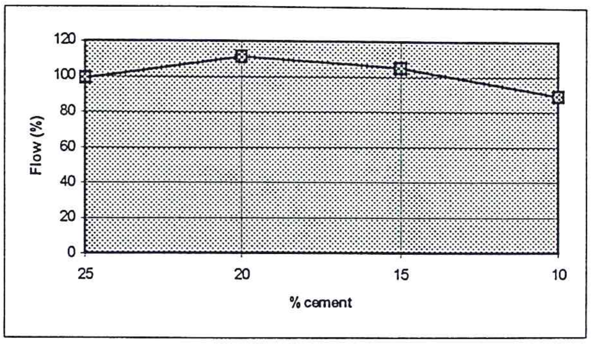
6.42 Fresh state characteristics

Besides the interpretation of hardened state results it is important to be able to assess the ease with which the mortar mixes were used for plastering by visually inspecting the actual plastering process.
Such information is extremely important since the final product quality is a function of the ability to use the fresh state mortar; a mason's opinion was asked on the ease of use of the mortar mixes since it is such people which will be using the sands. Furthermore, the mason could provide comparisons between different mortars used by him in the past to the ones under test.
When the trials were carried out, the quality of the mixes was also assessed by visual inspection and by patting the mixtures with a trowel.

6.43 Test results: properties of mortar for Sand 1 – Mix variable

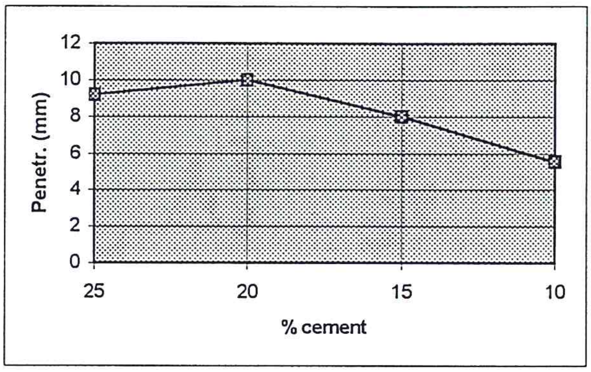
a. Flow

MIX	% CEMENT	W/C RATIO	FLOW (%)
A	25	1,15	99
B	20	1,6	111
C	15	2,3	105
D	10	3,8	89



b. Dropping Ball / Consistence Cone

MIX	% CEMENT	W/C RATIO	PENETR.	CONS.
			(mm)	CONE
A	25	1,15	9,2	16
B	20	1,6	10	16
C	15	2,3	8	17
D	10	3,8	5,5	16

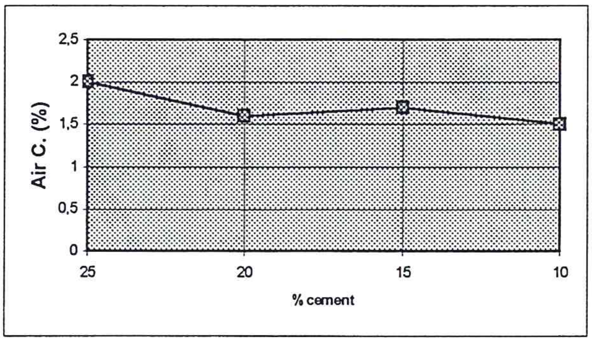


c. Water Retentivity

MIX	% CEMENT	WATER R.	BS SPECS.
		(%)	(%)
A	25	86	>= 88
B	20	84	>= 89
C	15	85	>= 90
D	10	83	>= 91

d. Air Content

MIX	% CEMENT	AIR C. (%)
A	25	2
B	20	1,6
C	15	1,7
D	10	1,5



e. Plastic Density

MIX	% CEMENT	PLASTIC D.
		(kg/m³)
A	25	1910
B	20	1865
C	15	1825
D	10	1780

f. Compressive Strength

MIX	% CEMENT	7 DAYS	28 DAYS	DENSITY	BS SPECS.
		(N/mm²)	(N/mm²)	(kg/m³)	(N/mm²)
A	25	11,6	15,1	2010	>= 11,0
B	20	6	7,2	1960	>= 4,5
C	15	3,5	4,3	1790	>= 2,5
D	10	1,8	2,3	1690	>= 1,0

6.44 Discussion of results

6.441 Workability

Workability increases together with water content then decreases above a certain value of water content.
Only mixes A and B have acceptable penetration values for the dropping ball test (recommended BS value 10.0mm).

Even though the flow table and dropping ball tests measure the same property (workability), the two tests do not appear to be compatible with each other. The dropping ball test yields reliable results only for cement rich mixes.

Note: High free water cement ratio obtained for all four mixes. This is a combination of two factors:

- High water demand due to fineness and high void content of Sand 1
- Low cement content for leaner mixes.

6.442 Air Content and Plastic Density

All four mixes show low air content values which are well below the maximum 7% limit placed by BS 4551.

Plastic density decreases as cement content decreases (accompanied by increase in water content to keep workability constant). Consequently, strength should decrease from mix A to D.

6.443 Water Retentivity

All the values are lower than what the Standards recommend. A possible explanation would be the presence of the high free water content of all four mixes facilitating movement of water to the mortar surface.

The results indicate that all the mortar mixes may have adhesion problems in plaster or render.

6.444 Compressive Strength

All the mixes meet the BS 4721 Specifications.

6.445 Optimum Mix for Sand 1 (without admixture) – OM_1

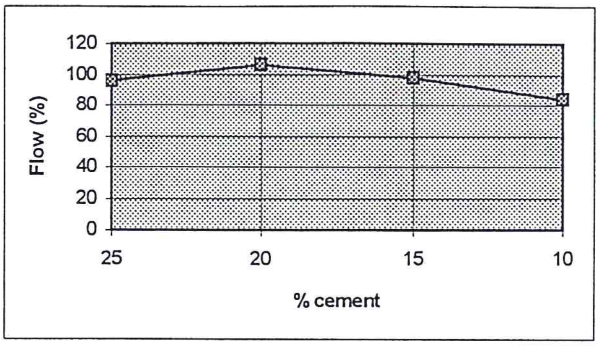
The feedback from the mason was that mix A and B were good mixes for plastering from his experience.
From all the tests performed the major problem lies with the low water retentivity especially for the leaner mixes.

In the light of the above and of the discussion of the results obtained, Mix B was considered as the optimum mix (OM_1).

6.45 Test results: properties of mortar for Sand 2 – Mix variable

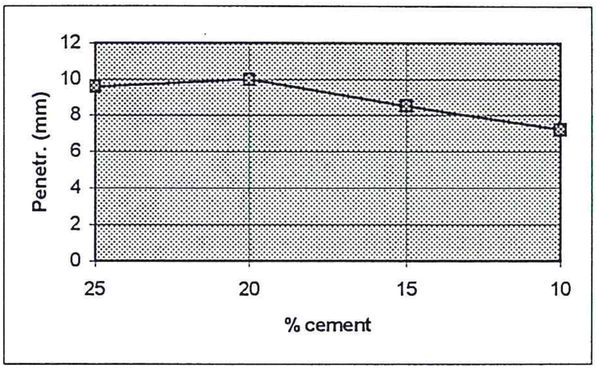
a. Flow

MIX	% CEMENT	W/C RATIO	FLOW (%)
E	25	0,55	96
F	20	0,75	106
G	15	1,10	98
H	10	1,60	84



b. Dropping Ball / Consistence Cone

MIX	% CEMENT	W/C RATIO	PENETR.	CONS.
			(mm)	CONE
E	25	0,55	9,6	16
F	20	0,75	10	16
G	15	1,10	8,5	16
H	10	1,60	7,2	17

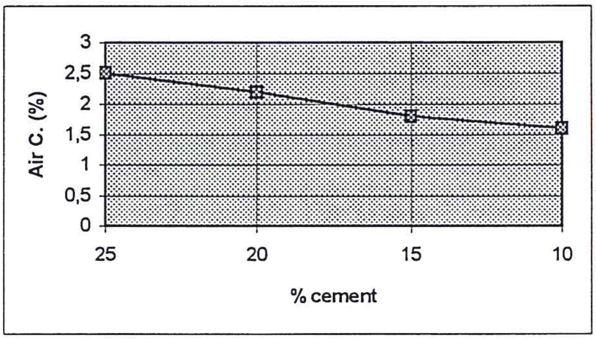


c. Water Retentivity

MIX	% CEMENT	WATER R.	BS SPECS.
		(%)	(%)
E	25	87	>= 88
F	20	85	>= 89
G	15	84	>= 90
H	10	80	>= 91

d. Air Content

MIX	% CEMENT	AIR C. (%)
E	25	2,5
F	20	2,2
G	15	1,8
H	10	1,6



e. Plastic Density

MIX	% CEMENT	PLASTIC D.
		(kg/m^3)
E	25	2512
F	20	2475
G	15	2426
H	10	2310

f. Compressive Strength

MIX	% CEMENT	7 DAYS	28 DAYS	DENSITY	BS SPECS.
		(N/mm^2)	(N/mm^2)	(kg/m^3)	(N/mm2)
E	25	22,3	33,5	2330	>= 11
F	20	13,5	23,2	2290	>= 4.5
G	15	7,5	12,5	2210	>= 2,5
H	10	4,3	6,0	2140	>= 1,0

6.46 Discussion of results

6.461 *Workability*

Workability increases with water content then decreases above a certain value of water content.
Only mixes E and F have acceptable penetration values for the dropping ball test.
The comment made in 6.441 on the dropping ball test is confirmed.

By visual inspection, mixes F,G and H seemed to be too lean with bleeding increasing from F to H.

6.462 Air Content and Plastic Density

The comments are the same as for Sand 1 (See 6.442).

6.463 Water Retentivity

Only mix E seems to give an acceptable value as per the recommendations of the Standards.

6.464 Compressive Strength

Compressive strength is inversely proportional to the sand / cement ratio and the water / cement ratio.
All the results are as expected and satisfy the Specifications.

6.465 Optimum Mix for Sand 2 (without admixture) – OM_2

According to the mason, the ideal mix for plastering would be somewhere between mix E and mix F.
As for Sand 1, the major problem lies with the low water retentivity values. This property is expected to be improved with the use of appropriate admixtures.

In the light of the above and of the discussion of the results obtained, Mix E was taken as the optimum mix (OM_2).

7. Admixtures

7.1 Introduction

Traditionally mortars used for rendering and plastering are of 1:3 (cement : sand) proportion similar to mixes A and E. The main advantage achieved by such a mortar would be superior strength. However, mortars for rendering and plastering are not load bearing structures, and therefore it would not be logical and economical in using such mortars unless a dense structure is needed in the context of the engineering work.

Furthermore, increasing the cement content has a tendency to increase the degree of shrinkage, which is not desirable. It follows that leaner mortar mixes may be more appropriate mixes and if possible should be used.
However, certain aggregates used in such proportions tend to produce harsh and unworkable mixes that tend to bleed in excess. This has been reflected in the results obtained for some of the mixes under investigation (6.44 & 6.46).

In the light of this, admixtures have been considered to help improve the quality and performance of the mortars under study.

7.2 Use of an air-entraining agent

This is incorporated in mortar mixes to enhance their workability and allow the mortars to remain in the plastic state for a longer time, reduce bleeding and segregation and increase the flow. It also helps in reducing shrinkage of hardened mixes by reducing the water/cement ratio for the same cement/sand ratio to achieve the same workability.

Entrained air increases the porosity of the mortar and this consequently results in a decrease in strength. Compared with the same mix without entrained air, the reduction of strength could be about 25%, but in practice, the improvement in workability allows the use of a smaller water content and the loss in strength can be kept below 10%.

The admixture used was an air-entraining agent of the brand CONPLAST having product name AE 300 from FOSROC (represented by Manfield Associates in Mauritius), which is a brown liquid.
This is a chloride free admixture based on neutralised vinsol resin. It is suitable for use with Ordinary Portland Cement and compatible with the retarder/plasticiser used. It complies with BS 5075:Part 1.

It has the following typical properties:

- Specific gravity : 1.02 at 20°C
- pH : alkaline
- Chlorides : nil to BS 5075.

See Product Data Sheet in Annex 4 for typical dosage rates specified by the manufacturer and for more information on this product.

Therefore both the improved cohesion and lower water content should improve bleeding, thus improve the water retentivity of the mortar mixes.

Since shrinkage is proportional to the water content, and it is possible to reduce the latter with air entrainment, the resultant mixes should shrink less.

7.3 Use of a retarder / plasticiser

This is a chloride free plasticising and retarding admixture, based on selected hydrocarboxylic materials, introduced within the water.
Its product name is CEBEX 305, from FOSROC. The admixture is suitable for use with Ordinary Portland Cement and compatible with the air-entraining agent used. It complies with BS 5075:Part 1.

See Product Data Sheet in Annex 5 for typical dosage rates specified by the manufacturer and for more information on this product.

7.4 Experimental work

7.41 Determination of optimum air content for mortar with the two sands

7.411 Procedure

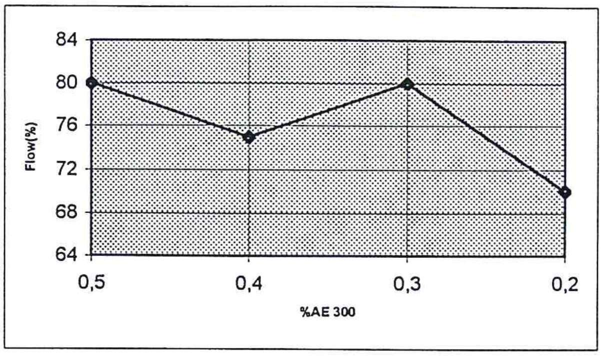
The same procedure as in 6.41 was followed.
The percentage of retarder was fixed to achieve 36 hours retarding - trial mixes gave a percentage of 1.0% retarder for 36 hours retarding.

The percentage of air was varied with the optimum mixes OM_1 for Sand 1 and OM_2 for Sand 2. The optimum percentage of air was determined in the light of the results for the six properties tested.

7.412 Test results: Properties of mortar for Sand 1 - % air variable

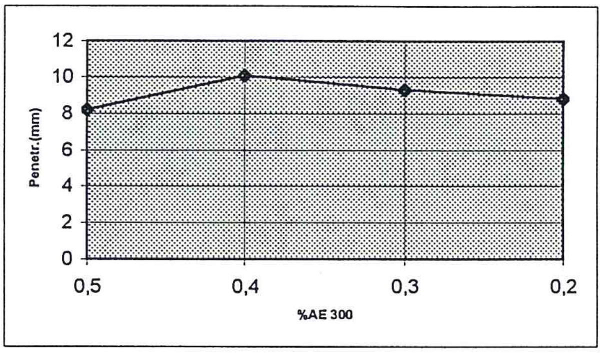
a. Flow

TRIAL	% AE 300	W/C RATIO	FLOW (%)
1	0,5	1,51	80
2	0,4	1,51	75
3	0,3	1,55	80
4	0,2	1,68	70



b. Dropping Ball / Consistence Cone

TRIAL	% AE 300	W/C RATIO	PENETR.	CONS.
			(mm)	CONE
1	0,5	1,51	8,2	16
2	0,4	1,51	10,1	16
3	0,3	1,55	9,3	16
4	0,2	1,68	8,8	16

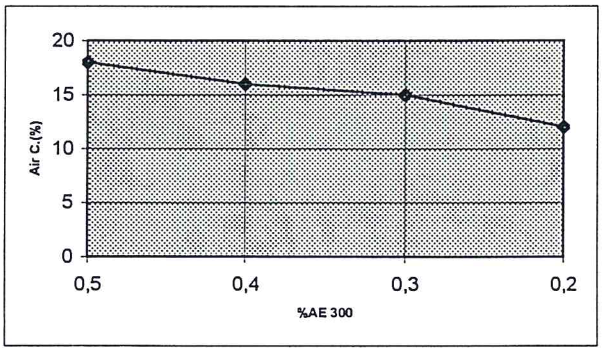


c. Water Retentivity

TRIAL	% AE 300	WATER R.
		(%)
1	0,5	99
2	0,4	95
3	0,3	97
4	0,2	97

d. Air Content

TRIAL	% AE 300	AIR C. (%)
1	0,5	18
2	0,4	16
3	0,3	15
4	0,2	12



e. Plastic Density

TRIAL	% AE 300	PLASTIC D.
		(kg/m^3)
1	0,5	1520
2	0,4	1560
3	0,3	1560
4	0,2	1570

f. Compressive Strength

TRIAL	% AE 300	7 DAYS	28 DAYS	DENSITY
		(N/mm^2)	(N/mm^2)	(kg/m^3)
1	0,5	4,1	6,9	1565
2	0,4	8,6	13,1	1560
3	0,3	10	15	1570
4	0,2	11,5	15,5	1585

7.413 Discussion of results

Water retentivity is improved as expected.

In fact, the test results do not help much in choosing an optimum percentage of air.
A percentage of AE 300 between 0.5 and 0.4% would give acceptable results overall.

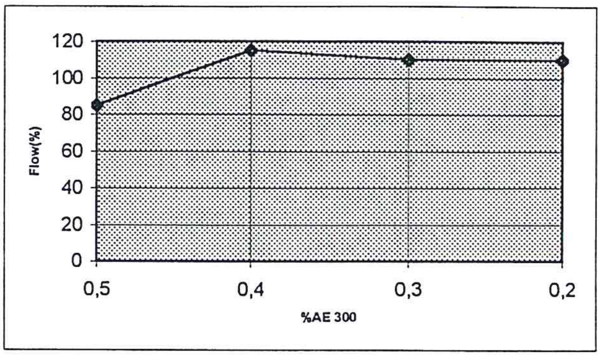
A 16% air content (0.4% AE 300) was taken as the optimum for the following reasons:

- This is 2% below the maximum percentage specified by BS 4721
- A maximum air entrainment is targeted because
  - Better workability, decrease in density, increase in ease of application
  - Lower water demand (W/C ratio), decrease in risk of shrinkage.

7.414 Test Results: Properties of mortar for Sand 2 - % air variable

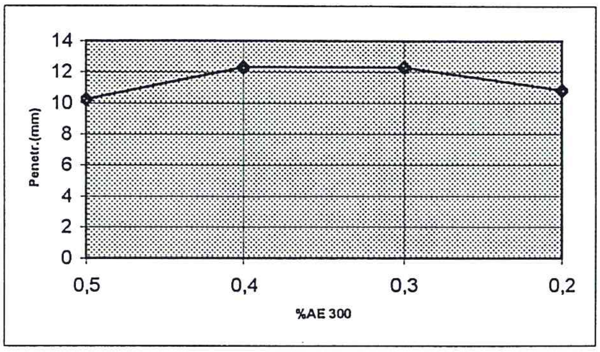
a. Flow

TRIAL	% AE 300	W/C RATIO	FLOW (%)
5	0,5	0,67	85
6	0,4	0,68	115
7	0,3	0,71	110
8	0,2	0,73	110



b. Dropping Ball / Consistence Cone

TRIAL	% AE 300	W/C RATIO	PENETR.	CONS.
			(mm)	CONE
5	0,5	0,67	10,2	16
6	0,4	0,68	12,3	17
7	0,3	0,71	12,3	17
8	0,2	0,73	10,8	16

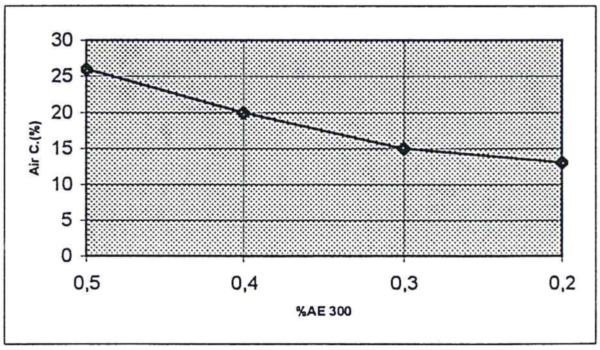


c. Water Retentivity

TRIAL	% AE 300	WATER R.
		(%)
5	0,5	98
6	0,4	91
7	0,3	93
8	0,2	97

d. Air Content

TRIAL	% AE 300	AIR C. (%)
5	0,5	26
6	0,4	20
7	0,3	15
8	0,2	13



e. Plastic Density

TRIAL	% AE 300	PLASTIC D.
		(kg/m^3)
5	0,5	1740
6	0,4	1820
7	0,3	1850
8	0,2	1910

f. Compressive Strength

TRIAL	% AE 300	7 DAYS	28 DAYS	DENSITY
		(N/mm^2)	(N/mm^2)	(kg/m^3)
5	0,5	4,1	7,9	1880
6	0,4	5	9	2010
7	0,3	6,2	10,1	1995
8	0,2	9,4	15,7	2030

7.415 Discussion of results

The comments are as for 7.413.

A 16% air content (0.325% AE 300) was taken as the optimum for the same reasons as in 7.413.

7.42 Determination of optimum mixes with admixtures for the two sands

7.421 Procedure

The same procedure as for 6.41 was used.

The admixtures were used in the following proportions:

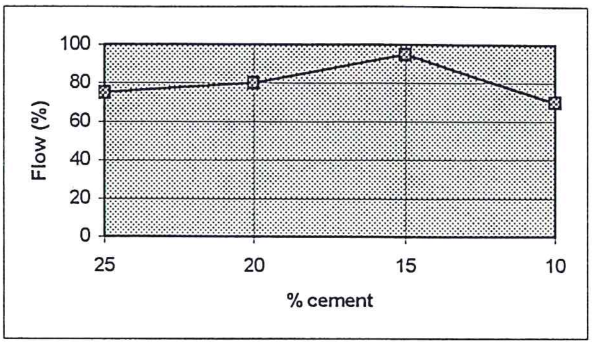
Sand	Mix	% CEBEX 305 (Retarder)	% AE 300 (Air-entrainer)
1	Variable (25-10% cement)	1.0	0.4
2	Variable (25-10% cement)	1.0	0.33

Table 7.421 Optimum admixture proportions

7.422 Test results: Properties of mortar for Sand 1 with admixtures - mix variable

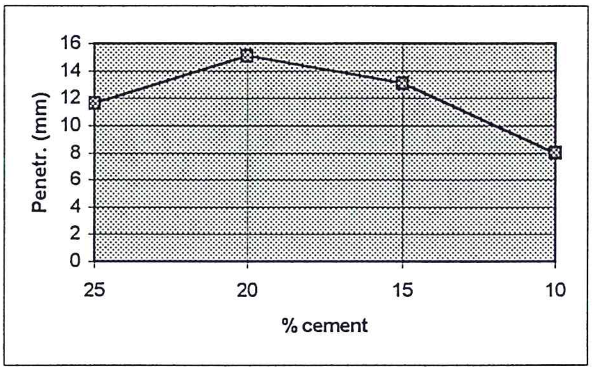
a. Flow

MIX	% CEMENT	W/C RATIO	FLOW (%)
A	25	1,27	75
B	20	1,58	80
C	15	2,22	95
D	10	3,26	70



b. Dropping Ball / Consistence Cone

MIX	% CEMENT	W/C RATIO	PENETR.	CONS.
			(mm)	CONE
A	25	1,27	11,6	16
B	20	1,58	15,1	17
C	15	2,22	13,1	16
D	10	3,26	8	16

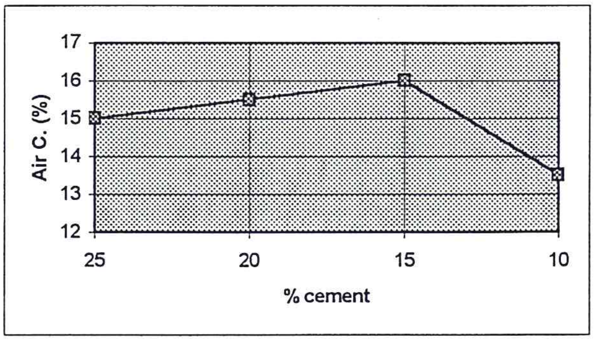


c. Water Retentivity

MIX	% CEMENT	WATER R.	BS SPECS.
		(%)	(%)
A	25	96	>= 88
B	20	96	>= 89
C	15	95	>= 90
D	10	89	>= 91

d. Air Content

MIX	% CEMENT	AIR C. (%)
A	25	15
B	20	15,5
C	15	16
D	10	13,5



e. Plastic Density

MIX	% CEMENT	PLASTIC D.
		(kg/m^3)
A	25	1540
B	20	1520
C	15	1472
D	10	1465

f. Compressive Strength

MIX	% CEMENT	7 DAYS	28 DAYS	DENSITY	BS SPECS.
		(N/mm^2)	(N/mm^2)	(kg/m^3)	(N/mm^2)
A	25	3,3	13	1950	>= 11,0
B	20	3,1	6,2	1860	>= 4,5
C	15	1,6	4	1775	>= 2,5
D	10	0,3	2,2	1650	>= 1,0

7.423 Discussion of results

7.4231 Workability

The workability of the mixes are improved (compared to same mixes without admixtures). In particular mix C gives a good workable mix. As said in 6.441, the dropping ball test does not give reliable results.

7.4232 Air Content and Plastic Density

Air content is around the targeted value of 16%.

The plastic densities are lower than without admixtures due to the presence of a retarder and a higher percentage of air in the mixes.

7.4233 Water Retentivity

This is definitely improved with the incorporation of the admixtures. All the mixes except D give satisfactory results with respect to BS Specifications.

7.4234 Compressive Strength

Strengths are slightly lower than the values without admixtures but all values satisfy BS Specifications.

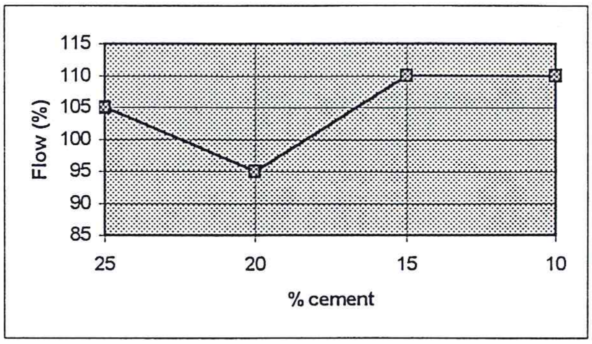
7.4235 Optimum mix with admixtures for Sand 1 – OM_{1a}

In the light of the above discussion of results, supported by the mason's opinion for suitable mixes for plastering and rendering, it can be said that the optimum mix lies somewhere between mix C and D.
The optimum was thus taken at 13% cement – OM_{1a}.

7.424 Test results: Properties of mortar for Sand 2 with admixtures – mix variable

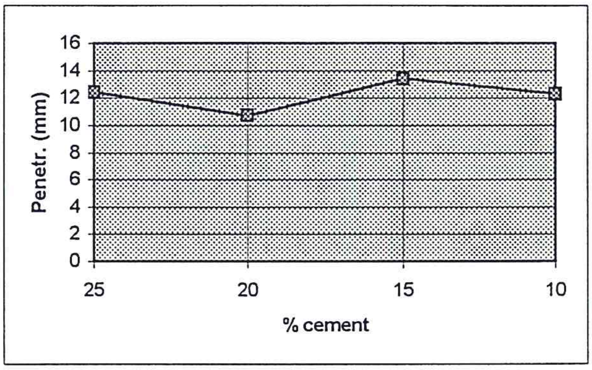
a. Flow

MIX	% CEMENT	W/C RATIO	FLOW (%)
E	25	0,96	105
F	20	1,28	95
G	15	1,37	110
H	10	1,74	110



b. Dropping Ball / Consistence Cone

MIX	% CEMENT	W/C RATIO	PENETR.	CONS.
			(mm)	CONE
E	25	0,96	12,4	15
F	20	1,28	10,7	16
G	15	1,37	13,4	16
H	10	1,74	12,3	16

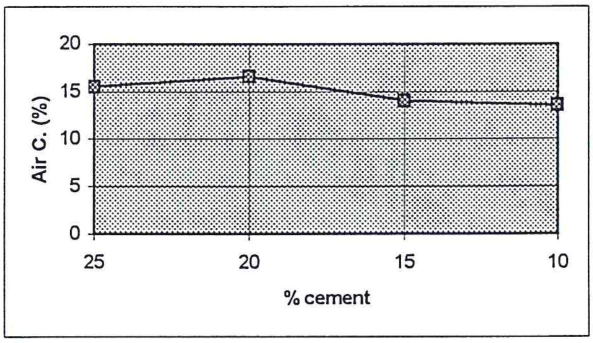


c. Water Retentivity

MIX	% CEMENT	WATER R.	BS SPECS.
		(%)	(%)
E	25	94	>= 88
F	20	90	>= 89
G	15	89	>= 90
H	10	90	>= 91

d. Air Content

MIX	% CEMENT	AIR C. (%)
E	25	15,5
F	20	16,5
G	15	14
H	10	13,5



e. Plastic Density

MIX	% CEMENT	PLASTIC D.
		(kg/m^3)
E	25	2126
F	20	2066
G	15	1976
H	10	1956

f. Compressive Strength

MIX	% CEMENT	7 DAYS	28 DAYS	DENSITY	BS SPECS.
		(N/mm^2)	(N/mm^2)	(kg/m^3)	(N/mm^2)
E	25	10,9	18,7	2040	>= 11,0
F	20	6,7	12,8	1955	>= 4,5
G	15	4,1	9,2	1925	>= 2,5
H	10	1,9	3,9	1890	>= 1,0

7.425 Discussion of results

7.4251 Workability

In opposition to Sand 1, the workability of the mixes is not considerably improved by the admixtures (compared to same mixes without admixture).
Only mix G gives an acceptable workable mix.

The high flow values can be explained by the segregation in the mixes: coarse particles tend to separate from the paste which becomes less cohesive, hence greater flow.
The dropping ball test, as said earlier, does not give reliable results.

7.4252 Air Content and Plastic Density

Air content values are around 16% as expected.

Plastic densities are lower than without admixtures due to the presence of a retarder and a higher percentage of air in the mixes.

7.4253 Water Retentivity

In general water retentivity is improved by the use of the admixtures.
However, mixes G and H still do not satisfy the requirements of BS 4721. These mixes still showed segregation and bleeding during their preparation.

7.4254 Compressive Strength

Strengths are considerably lower than the values without admixtures but they all satisfy BS 4721 Specifications.

7.4255 Optimum mix with admixtures for Sand 2 – OM_{2a}

In the mason's opinion, mixes E and F are acceptable for use in plaster and render.

This, together with the deductions from the above discussion of results, tends to lead to the conclusion that mix F can be considered as the optimum (20% cement) – OM_{2a}.

7.5 Recapitulation of findings for optimum mixes of the two sands

	Sand	% cement by weight of dry materials	Cement : sand proportions by volume	% Retarder	% Air - entrainer
Opt. Mix OM_{1a} (Consistence cone 16)	1	13.0	1:6-7	1.0	0.4
Opt. Mix OM_{2a} (Consistence cone 16)	2	20.0	1:4	1.0	0.33

Table 7.5 Optimum mixes with admixtures for Sands 1 and 2

8. Shrinkage

8.1 Introduction

Depending upon the environment in which a mortar hardens, there may be loss or gain of moisture by the latter. Consequently, the mortar may undergo large changes in volume and although expansion is rarely a problem, shrinkage may lead to cracking.
When the mortar is in the plastic state it loses water, if it is not in a moist environment, by evaporation and by absorption of water by aggregates and by the backing surface. This results in a volumetric contraction and is termed plastic shrinkage.

The most convenient and economical way to reduce plastic shrinkage in practice is by dampening of the backing surface prior to plastering. This reduces the absorption of moisture from the fresh mortar, thus reducing plastic shrinkage.

After the initial plastic shrinkage has occurred, the mortar continues to lose water from its voids and capillary pores, while it dries. This is known as drying shrinkage. After an initial high rate of drying shrinkage, the mortar continues to shrink for a long period of time but at a decreasing rate.

8.2 Unrestrained shrinkage

When shrinkage tests are performed on prism samples according to BS 1881:1970, the mortar prism samples are allowed to shrink freely, therefore representing unrestrained shrinkage of mortars.
In contrast, the shrinkage of mortars on a backing surface is restrained due to the latter inhibiting mortar movement. This is termed restrained shrinkage.

Though unrestrained shrinkage does not reflect the actual behaviour of a mortar in practice, it can nevertheless be used to predict the actual restrained shrinkage.
Correlations exist, from past investigations and research works between unrestrained and restrained shrinkage for a given sand, mix design, consistency, backing surface and curing conditions.The correlations can be used to estimate values of restrained shrinkage for a mortar by performing the prism shrinkage test on the mortar sample.
The results obtained can forecast whether problems relating to high shrinkage could occur in mortars as plasters and renders. If so, such mortars can be discarded or modified before actually using them on a construction site.

8.21 Experimental work

8.211 Procedure

Due to lack of time and equipment shrinkage tests were not performed on all the test mixes for the two sands under investigation.
For each sand, a rich and a lean mix were chosen for shrinkage investigation. The behaviours of the intermediate mixes were deduced by interpolation.
In particular, the behaviours of OM_{1a} and OM_{2a} were looked at and compared.

The mixes investigated were as follows:

Mix	Sand	% Cement	% Retarder	% Air-entrainer
A (Consistence cone 16)	1	25	1.0	0.4
D (Consistence cone 16)	1	10	1.0	0.4
E Consistence cone 16)	2	25	1.0	0.33
G (Consistence cone 16)	2	15	1.0	0.33

Table 8.211 Specimens for Prism Shrinkage tests to BS 1881:1970

The prism shrinkage was done in accordance with BS 1881:Part 5 1970. The prism specimens had a size of 75 mm x 300 mm. For each mix tested a total of three specimens were cast. Only concordant results were retained among the specimens.

The values obtained represent ultimate shrinkage since test procedures have ensured that the specimen does not shrink any further. The values can be expressed in microstrain or in percentage.

8.212 Test results: Unrestrained shrinkage for Sands 1 and 2

DATE: 08/08/00
TEST: Prism Shrinkage on mortar specimens

PRISM NO.	% CEMENT (%)	DATE CASTED	DIMENSIONS (mm)	ULTIMATE SHRINKAGE (%)
A1	25	30/06/00	75x75x299	0,080
A2	25	30/06/00	75x75x300	0,090
A3	25	30/06/00	75x75x301	0,095
D1	10	30/06/00	75x75x300	0,060
D2	10	30/06/00	75x75x300	0,065
D3	10	30/06/00	75x75x300	0,060
E1	25	04/07/00	75x75x300	0,080
E2	25	04/07/00	75x75x301	0,080
E3	25	04/07/00	75x75x301	0,085
G1	15	05/07/00	75x75x300	0,060
G2	15	05/07/00	75x75x300	0,100
G3	15	05/07/00	75x75x301	0,065

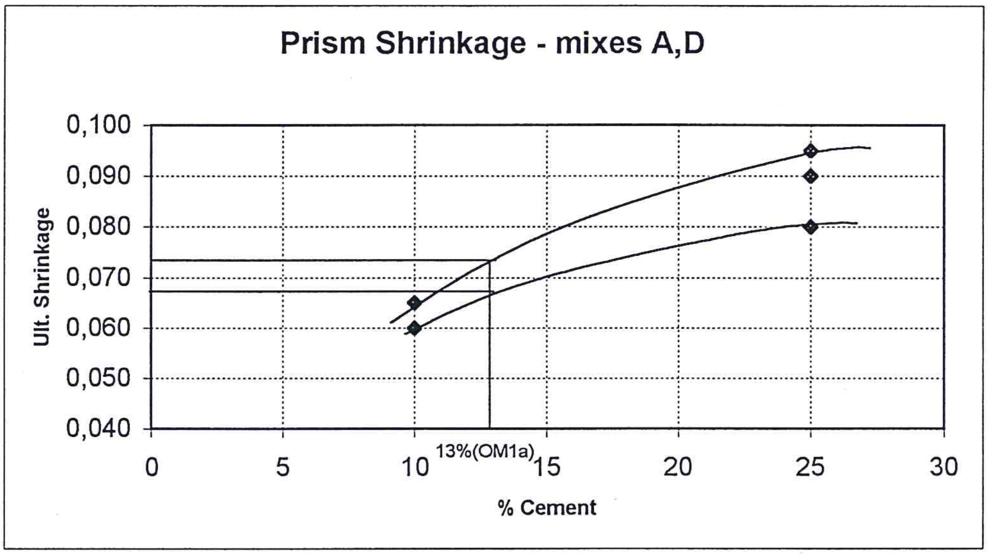


Fig. 8,2121 Unrestrained shrinkage test results for Sand 1

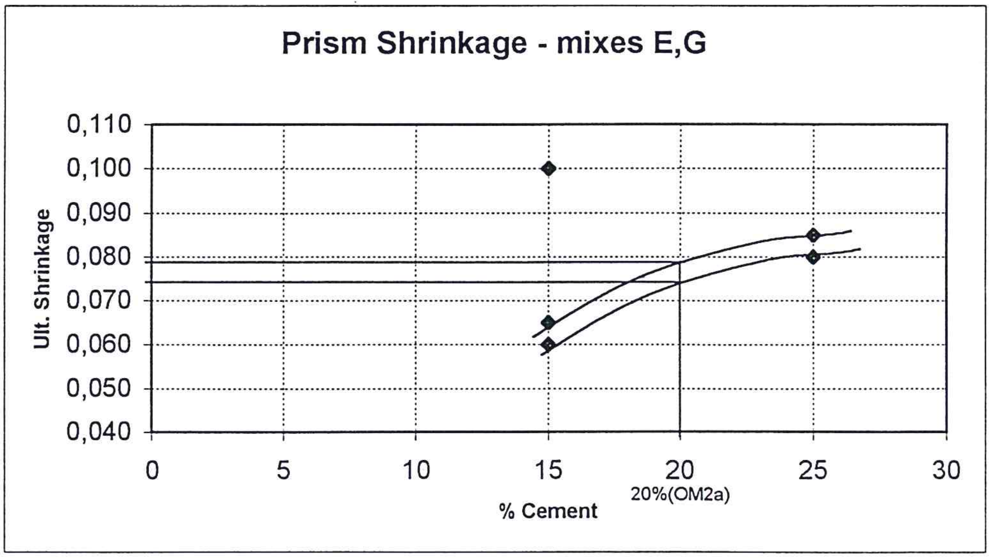


Fig. 8,2122 Unrestrained shrinkage test results for Sand 2

8.213 Discussion of results

Shrinkage values are higher for Sand 1 compared to Sand 2, especially for rich mixes. For the same mix composition, consistency and curing conditions, Sand 1 exhibits higher shrinkage than Sand 2.

However the optimum mix with admixture for Sand 1, OM_{1a}, is expected to exhibit lower shrinkage than the optimum mix with admixture for Sand 2, OM_{2a}.

8.22 Prediction of Restrained shrinkage from Unrestrained shrinkage results

The sands investigated, the mix designs and consistency being the same, for cellular blocks as backing surface, and for similar temperature and humidity conditions, the following predictions will be considered as approximately correct.

8.221 Use of R_{20}/F, R_{50}/F and R_{90}/F correlations

Sand	1		2	
Mix	A	D	E	G
Prism shrinkage (x 10^{-6}), F (mean of concordant values of 3 specimens)	883	617	817	625
R_{20}/F (%)	30	32	29	32
20 days restrained shrinkage (x 10^{-6}), R_{20}	265	197	237	200
R_{50}/F (%)	42	51	41	52
50 days restrained shrinkage (x 10^{-6}), R_{50}	371	315	335	325
R_{90}/F (%)	46	53	42	54
90 days restrained shrinkage (x 10^{-6}), R_{90}	406	327	343	338

Table 8.221 Predicting restrained shrinkage from unrestrained shrinkage values

R_{20}/F, R_{50}/F, R_{90}/F correlations source for Sand 1: Suitability of marine-dredged fine sand for rendering and plastering – Meerun Muslim Zahur – B Eng Civil Eng Univ of Mtius – March 1999.
$R_{20}/$, R_{50}/F, R_{90}/F correlations source for Sand 2: Suitability of crushed basalt sand for rendering and plastering – Essoo Nuthooram – B Tech Civil Eng Univ of Mtius – April 1991.

8.222 Discussion of results

The deductions in 8.213 are confirmed in the case of restrained shrinkage.

But this empirical method of prediction remains very theoretical and approximate. Restrained shrinkage should be investigated by actual practical testing of mortar on a backing surface and monitoring of the shrinkage over a suitable length of time.

8.3 Restrained shrinkage - Investigation of plaster and render on cellular blocks

If the tests performed earlier on the mortar mixes reflect the actual use and site conditions as far as possible then a better understanding and more precise information on setting the performance of the mortars can be obtained.

With this in mind a small-scale site simulation was carried out. The optimum mortar mixes determined were plastered onto walls of cellular blocks and the plastered surfaces monitored. When a mortar is restrained internal stresses build up. As the shrinkage process continues a point is reached, depending on the strength, where the mortar cannot withstand the stresses and fails in the form of cracks. Therefore, the formation of cracks is a function of a shrinkage occurring and is more likely to occur with higher shrinkage.

It is the drying shrinkage that is of more importance since it is this process which will influence the mortar while in the hardened state. Drying shrinkage depends on several factors, some of which are as follows:

1. Water content
2. Aggregate type
3. Cement content
4. Relative humidity.

8.31 Simulation of plaster and render

This consisted of four walls of cellular concrete blocks to which plaster and render were applied, as shown by the table below.

Wall No.	Opt. Mix	Conditions	Simulation
1	OM_{1a}	Interior	Plastering
2	OM_{2a}	Interior	
3	OM_{1a}	Exterior	Rendering
4	OM_{2a}	Exterior	

Table 8.31 Simulation of plaster and render on cellular blockwork

Concrete blockwork was used since this represented the backing surface that is most commonly used for rendering and plastering.

The procedure adopted was to wet the backing surface then apply the mortar in one coat of around 12 mm. The mortar coat was then levelled and trowelled to produce the finished surface.
In certain places the mortar surface was even trowelled using a plastic float to see whether a good finished surface could be obtained.

8.32 Observation

The observation exercise consisted of monitoring the shrinkage of the plastered surfaces.
The surfaces were inspected for cracks, loss of adhesion and crazing on a daily basis, over a period of 5 weeks.

8.33 Results and discussion

The table below summarises the findings over the period of observation (Weeks 1 to 5).

"X" denotes "None"

"NC" denotes "No change".

Wall No.	Mix	Application	Finished surface	Cracks					Loss of adhesion					Crazing				
				WK1	WK2	WK3	WK4	WK5	WK1	WK2	WK3	WK4	WK5	WK1	WK2	WK3	WK4	WK5
1	OM_{1a}	Easy & Quick	Good & Smooth	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	OM_{2a}	Less easy & Slower	Less Smooth	X	X	Faint Minor	NC	NC	X	X	X	X	X	X	X	X	X	X
3	OM_{1a}	Easy & Quick	Good	X	X	X	X	X	X	X	X	X	X	Slight	NC	NC	NC	NC
4	OM_{2a}	Less easy & Slower	Good	X	X	X	X	X	X	X	X	X	X	Slight	NC	NC	NC	NC

Table 8.33 Findings of investigation of plaster and render on cellular block walls

In general, none of the mixes showed any difficulties in terms of application while being used by the mason and appeared to be very workable due to the air entrainment.
All the problems associated with low water retentivity were not seen and the mortars were used with ease.
The findings are more or less in accordance with the results of unrestrained shrinkage in 8.212 and prediction of restrained shrinkage in 8.221.

OM_{1a} (Sand 1) appears to be slightly better than OM_{2a} (Sand 2) for use as plaster and render. Shrinkage is less in this case and this can be explained as follows:

Sand 1 is finer than Sand 2. The fineness increases the bond between the backing surface and the mortar because the fine particles can fill the surface roughnesses of the blockwork more effectively.
The adhesion between the backing surface and the mortar is stronger, this results in more restraint being provided by the backing surface to the shrinkage of the mortar layer, hence shrinkage is less.

But overall there was no major problem with the two sands; their use in plaster and render can be considered as satisfactory as far as shrinkage is concerned.

9. Economics of the use of crushed basalt sand and dredged coral sand in mortar

So far, the two sands have been assessed from a technical point of view. However, a feasibility study is incomplete unless a financial appraisal is undertaken.

To assess, in monetary values, the implication of the use of the sands in mortar, a study of the cost of material for the production of mortars with Sand 1 (optimum mix OM_{1a}), Sand 2 (optimum mix OM_{2a}) and lagoon coral sand (without admixture) - the traditional mortar used on site - was carried out and the results compared.

Calculations were based on the following data:

Component	Cost
Ordinary Portland Cement	Rs 80.00 per 50Kg
Dredged coral sand (Sand 1)	Rs 335.00 per ton
Crushed basalt sand (Sand 2)	Rs 240.00 per ton
Lagoon coral sand	Rs 405.00 per ton
Air-entrainer AE 300	Rs 28.36 per litre
Retarder CEBEX 305	Rs 41.60 per litre

Table 9 Costs of studied mortar components

Note: All prices are VAT exclusive.

9.1 Cost of material for 1 m^3 of mortar with Sand 1, Sand 2 and lagoon coral sand

Mix	Consist. Cone	Mix proportions	Total Cost of material per m^3 of mortar (Rs.)	Savings per m^3 over Lagoon coral sand (Rs.)
OM_{1a} (Sand 1)	16	1 cement:6 sand (by volume)1.0% retarder 0.4% air-entrainer	890	385
OM_{2a} (Sand 2)	16	1 cement:4 sand (by volume)1.0% retarder 0.33% air-entrainer	1010	265
Lagoon coral sand (without admixture)	16	1 cement:3 sand (by volume)	1275	-

Table 9.1 Cost effectiveness of dredged coral sand and crushed basalt sand

The results tabulated in table 9.1 show that savings of the order of:

- Rs. 300 to 400 per m^3 of mortar can be achieved when dredged coral sand is used instead of lagoon coral sand

- Rs. 200 to 300 per m^3 of mortar can be achieved when crushed basalt sand is used instead of lagoon coral sand.

It can be said that the use of admixtures increases the cost effectiveness of a mortar in that the saving in cement supersedes the cost of the admixtures.

With the rapid depletion of coral sand, its scarceness will increase its price so that it will become even cheaper to use dredged coral sand and crushed basalt sand.

10. General conclusions and discussion

10.1 Crushed basalt sand

10.11 Suitability of crushed basalt sand for rendering and plastering

Because coral sand was in abundance and thus cheaply available as compared to crushed sand, coral sand has for long been the only source of sand for construction. However, because it is becoming scarce, the construction industry is having recourse to other alternatives, among which is crushed basalt sand.

Two types of crushed sand have been identified: the "sugar-size" and the more recently available "impact-crushed" basalt sand.
The "sugar-size" sand has proved to be a difficult material to be utilised for plastering and rendering.

Investigations were carried out on the "impact-crushed" basalt sand to assess its behaviour in plasters. The following conclusions can be drawn from these investigations:

1. The coarse particles create problems when used in plasters, in so far as they reduce the ease of application of the mortar and that they tend to segregate when work is done on the mortar.
   Therefore a modified sample was used where only the coarse particles (>2.36 mm) were removed. The percentage of particles rejected, which amounted to about 19%, can be used in fills or in mass or fill concrete.

2. The basalt sand has a fines content in excess of that specified in the Standards. The percentage passing a 75 micron sieve is 18% whereas BS 1199:1976 specifies that this should not be greater than 5%.
   However, this factor does not seem to adversely affect the shrinkages or the strengths of the resulting mortars, but instead improves their workability and entails savings in cement. Thus, the maximum limits set in the Standards for fines content with a view to guarding against excessive shrinkage appear to be unnecessarily harsh, at least in the case of this basalt sand.

3. Compared with coral sand mortar, the basalt sand mortar proves to be somewhat harsh. However, this can be improved by the use of admixtures, such as an air-entraining agent and a plasticiser / retarder which enable water reduction in the mortar while maintaining the flow characteristics of the latter.

4. With the incorporation of admixtures, not only was workability improved but savings in cement could be achieved.

5. The optimum mix proportions with admixtures were found to be as follows (at a consistence cone of 16):

   20% cement by weight of dry materials

   cement : sand, 1 : 4 by volume

   1.0% CEBEX 305 retarder for 36 hours retarding

   0.33% AE 300 air-entrainer for 16% air content.

6. Shrinkage measurements on prism specimens have shown that shrinkage of the crushed basalt sand mixes is lower than for the dredged coral sand for rich mixes especially.

7. Observation of restrained shrinkage on a backing surface (cellular blockwork) has shown satisfactory performance of the optimum mortar mix (with admixture) of the crushed basalt sand. No major problems of cracking, loss of adhesion or crazing were observed.

10.12 Source of basalt sand

The production of basaltic sand from crushed rock is obviously dependant on the availability of the raw material. At present there are not many operating quarries in Mauritius. The major source of raw material for sand from rock crushing continues to be surface rock.

The Prime Minister's derocking scheme, primarily focused on increasing and maximising the amount of available land for agricultural production, particularly cultivation of sugar cane, has made available some 900,000 tonnes of rock annually. Of this about 300,000 tonnes are utilised for crushing by existing stone-crushing plants, while the remaining amount are being stockpiled in the fields for future use.

This situation has partly arisen as a result of the reluctance of some small planters to group themselves under a scheme which would enable quick disposal of rocks removed from the fields to the stone crushing plants. At present the stone crushers are finding it administratively difficult to negotiate with each individual small planter for the procurement of their raw material.

10.13 Environmental problems of stone crushing

Most, if not all, industrial activities are inevitably accompanied by environmental problems. It is thus futile to presume that stone crushing activities can be carried out at no cost to the environment.

The most obvious disturbances to the environment are noise, vibrations, dust emissions and waste slurry. Of these the first two appear to be relatively minor compared to the dust and mud problems.
Significant amounts of dust are generated which have a nuisance implication and present a health hazard to the plant operatives if not carefully managed.
Solutions to dust generation range from allowing dispersion to the atmosphere to containment systems.
Washing of the crushed aggregates requires treatment and the fines once removed also require disposal.

10.14 Conclusion on the suitability of crushed basalt sand for rendering and plastering

The crushed basalt sand can be made suitable for plastering and rendering purposes.

The shape, grading, relative density and shrinkage characteristics of basalt sand are hindering factors in its application for rendering and plastering purposes.
But these hindering factors can be considerably improved through the use of admixtures like air-entraining agents and plasticisers / retarders.

The optimum mix with admixtures for the crushed basalt sand has proved to be suitable, from a performance point of view, even though it has a higher cement content (20%) than the optimum mix for the dredged coral sand (13%).

Also, the optimum mix proves to be more economical than the traditional mortar mix with lagoon coral sand used on construction sites.

10.2 Dredged coral sand

10.21 Suitability of dredged coral sand for rendering and plastering

One of the possible sources of coral sand to replace lagoon coral sand is from marine origin. With the use of a mechanical dredging method, outer-lagoon coral sand was extracted from the sea bed. The sand was found to be of finer nature than the traditional lagoon coral sand.

So far little research has been performed on this sand to assess its suitability for rendering and plastering purposes.
One of the main objectives of this project has been to address this lack of research through tests performed in accordance with British Standards.

From the investigation, the main conclusions that can be drawn are as follows:

1. The sieve analysis tests showed that the coral sand was of very fine nature but still within the acceptable limits given in BS 1199:1976 for rendering and plastering.

2. The dredged coral sand proved to be efficient because of its rounded particles, similar to those of lagoon coral sand.

3. With respect to the tests carried out on the mortar mixes, all except the water retentivity test was found to be within the required range given by the BS 4721:1981. This was corrected, and all BS requirements met, through the use of admixtures.

4. The use of admixtures brings a reduction in water content together with an improvement in workability.

5. The use of admixtures appears to be more effective, as far as a reduction in shrinkage is concerned, with rich mixes.

6. Restrained shrinkage seems to level out within the first two weeks after plastering, after which only minor fluctuations are expected with time.

7. Even though shrinkage measurements have proved to be higher with this sand compared to the crushed basalt sand in general, for the optimum mix with admixture, however, the shrinkage was less.

8. Observation of restrained shrinkage on cellular blockwork with the optimum mortar mix (with admixtures) of the sand has shown no major problems of cracking, loss of adhesion or crazing.

9. The optimum mix proportions with admixtures were found to be as follows (at a consistence cone of 16):

   13% cement by weight of dry materials

   cement:sand, 1:6 - 7 by volume

   1.0% CEBEX 305 retarder for 36 hrs retarding

   0.4% AE 300 air-entrainer for 16% air.

10.22 Conclusion on the suitability of dredged coral sand for rendering and plastering

The dredged coral sand can be used in mortars for plastering and rendering satisfactorily. However the incorporation of admixtures like air-entraining agents and plasticisers / retarders is recommended.

The physical characteristics of the sand are closer to those of the lagoon coral sand as compared to the crushed basalt sand.

The optimum mix with admixtures for the dredged coral sand satisfies all BS requirements and gives satisfactory performance with respect to shrinkage.
Its low cement content (13%) compared to the optimum mixes with basalt sand (20%) or with traditional lagoon coral sand (25%) makes it a very economical mix to be used on construction sites.

10.23 Comparison of the dredged coral sand and the crushed basalt sand as an alternative to lagoon coral sand

The dredged coral sand would be a preferred alternative to lagoon coral sand than the crushed basalt sand because it embodies, to a greater extent, the properties of coral sand:

1. As opposed to basalt sand, the dredged sand is more easily made use of because of its uniformly distributed grading and smoother particle shape.

2. The smoother texture of mortar mixes allows for an easier flow during application.

3. The dredged coral sand has a fines content passing a 75 micron sieve of 2%, which conforms to the BS 1199:1976 recommendation of $\leq$5%. The basalt sand fines content would however approximate 20%.

4. The finer particles in the dredged coral sand, as opposed to the basalt sand, allow for greater adherence to backing surfaces when plastering. Hence, lower level of shrinkage and lower risk of masonry surface spalling off is expected.

5. Using basalt sand as an alternative to lagoon coral sand would require that the coarser particles be removed and that admixtures be used. This is not compulsory with the dredged coral sand since it embodies characteristics closer to lagoon coral sand. The workability of mortars are therefore better, entailing savings in cement.

10.24 The conditions for satisfactory performance of the dredged coral sand in practice

The shift from the use of lagoon coral sand to the alternative dredged coral sand in the construction industry is one that needs to be well managed.
Workers who are used to working with lagoon sand will have to adjust and adapt to new ways of working with this new sand.

An awareness / informative campaign is therefore of essence in order to achieve the following:

- Ensure the understanding of the need to shift away from lagoon coral sand.
  In this connection, Government has already announced measures for the complete ban of lagoon sand extraction by August 2001.

- Understand the benefits of using the dredged coral sand

- Inform users of the quality of the sand and of the ways in which it is best used.

11. Recommendations for further work

Suggestions for further works as a continuation to this project are as follows:

1. From the tests performed on the mortar mixes as plasters it has been seen that a rough backing surface significantly restrains shrinkage of the mortar mixes.
   Restrained shrinkage has been investigated only on the basis of observation; this investigation could be quantified by actual measurement of shrinkage by the use of a strain gauge and demec points placed on the plastered surface, and recording of readings over a suitable length of time.
   From the measurement of the restrained shrinkage of the mortar mixes the amount of restrained action can be found.

2. The mortar mixes used through this project have been plastered on rough textured backing surface (blockwork), which is not always the case during construction. Experiments can be performed by taking the mortar mixes and plastering them on to smoother surfaces, such as concrete beams and columns, and then monitor the resulting shrinkage.

3. The shrinkage of the mixes without admixture has not been investigated due to lack of time and equipment. This would be interesting to be done, as comparison with the results with admixture would then prove the efficiency of the admixtures to a greater extent.

4. Even though BS Specifications were used as guidelines throughout the investigation of the properties of mortar using the two sands, and the properties of mortar mixes using the two sands compared to each other, it would have been interesting to have done the whole investigation procedure with mortar using lagoon coral sand (the commonly used sand) and compare the results with those of the two sands studied.

5. Mortars with the crushed basalt sand were found to be harsh for application and showed poor workability without the use of admixtures.
   Investigations can be made to look for solutions to improve the workability of basalt sand mortar. For example the use of lime or of coal ash in basalt sand mortars can be investigated.

6. From the grading of the two sands:

- The dredged coral sand has a grading curve very close to the limits set out by BS 1199:1976
- The crushed basalt sand has very fine and coarse particles so that part of its grading curve lies outside the BS 1199 limits.

Ideally, a grading curve should pass through the centre of the BS 1199:1976 limits.

Blends of the two sands can therefore be investigated in order to achieve this.

From the individual gradings of Sand 1 and Sand 2, the following grading assessment gives the results of the blends which are closest to the ideal possible grading.

Sieve (mm)	BS 1199 LIMITS (%) Type B		%Passing				
			SAND 1	SAND 2	40%S1+ 60%S2	50%S1+ 50%S2	60%S1+ 40%S2
0,075	0	5	2	22	14	12	10
0,15	0	20	20	32	27,2	26	24,8
0,30	5	75	63	44	51,6	53,5	55,4
0,60	55	100	88	59	70,6	73,5	76,4
1,18	70	100	95	76	83,6	85,5	87,4
2,36	80	100	99	99	99	99	99
5,00	95	100	100	100	100	100	100
6,30	100	100	100	100	100	100	100

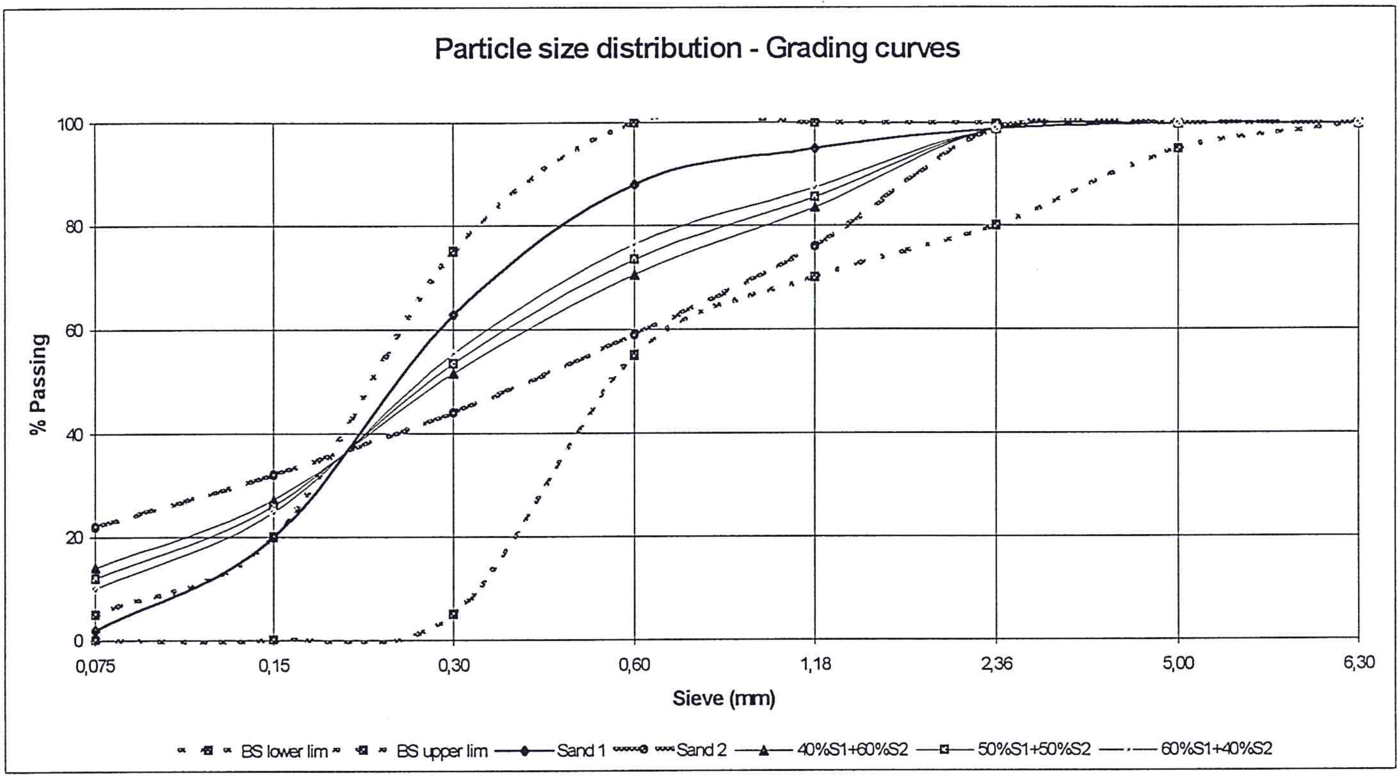


Fig. 11 Grading assessment of blends of Sand 1 and Sand 2

The ideal possible blend lies between 40% Sand1 – 60% Sand 2 and 60% Sand 1 – 40% Sand 2.

This blended sand is expected to give even better mortars than Sand 1 and Sand 2 because of its better grading and lesser voids with even greater savings in cement.

The whole investigation procedure with mortar using this blended sand can therefore be carried out (optimum mixes, use of admixtures, shrinkage properties...) to assess its suitability for plastering and rendering.

The optimum mortar mix with the blended sand is expected to have even lower cement content than in the case of the two sands studied, hence more economical and lesser risk of shrinkage problems.

From a technical and performance point of view the use of this blended sand in mortar is expected to be very interesting and satisfactory.
However the economics needs to be closely studied, in particular the additional cost incurred in the blending operation.

References

1. BS 1199 : 1976, Specifications for building sands from natural sources.
2. BS 4551 : 1980, Methods of testing for mortars, screeds and plasters.
3. BS 4721 : 1981, Specifications for ready-mixed building mortars.
4. BS 812 : 1975 Part 2, Physical properties.
5. BS 1881 : 1970, Specifications for methods of testing hardened concrete for other than strength.
6. E. Nuthooram,1991, Suitability of crushed basalt sand for rendering and plastering.
7. M.Z. Meerun, 1999, Suitability of marine-dredged fine sand for rendering and plastering.
8. D. Walton, Building construction principles and practices.
9. M.R. Rixon, Concrete Admixtures : Use and applications.
10. R. Hanumunthadu, 1988, Replacement of coral sand by rocksand for internal plastering and external rendering.
11. B.K. Baguant & C.P. François, 1990, Mauritius Report on Institutional Collaboration to promote the use of replacement construction materials as an alternative to coral sand depletion.
12. R.J. Cox, J.P. Hudson, N. Sooreedoo, 1993, AWACS Report - Mauritius Sand Dredging Study.

Annexes

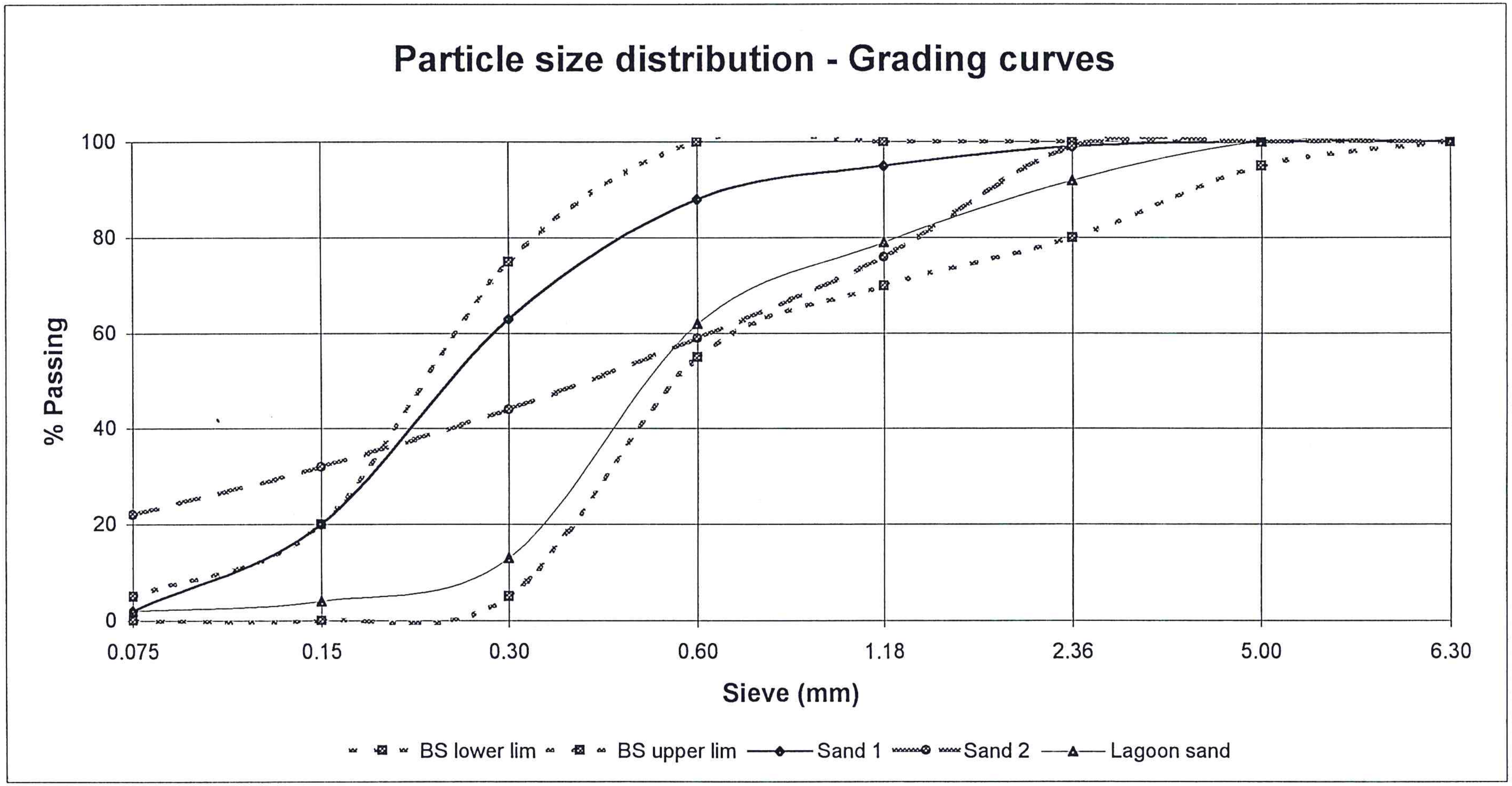
MRC PSCR - Work Programme

	May 00		June 00				July 00				August 00				September 00				Oct. 00	
	wk 3	wk 4	wk 1	wk 2	wk 3	wk 4	wk 1	wk 2	wk 3	wk 4	wk 1	wk 2	wk 3	wk 4	wk 1	wk 2	wk 3	wk 4	wk 1	wk 2
i. Material characteristics																				
a. Grading BS 1199: 1976																				
b. Relative density BS 812: Part 2																				
c. Water absorption BS 812: Part 2																				
d. Bulk density BS 812: Part 2																				
e. Percentage voids BS 812: Part 2																				
ii. Characteristics of fresh mortar - without admixture																				
a. Flow BS 4551: 1980																				
b. Consistency BS 4551: 1980																				
c. Water retentivity BS 4551: 1980																				
d. Air content BS 4551: 1980																				
e. Plastic density BS 4551: 1980																				
iii. Characteristics of hardened mortar - without admixture																				
a. Compressive strength BS 4551: 1980																				
iv. Characteristics of fresh mortar - with admixtures																				
a. Flow BS 4551: 1980																				
b. Consistency BS 4551: 1980																				
c. Water retentivity BS 4551: 1980																				
d. Air content BS 4551: 1980																				
e. Plastic density BS 4551: 1980																				
v. Characteristics of hardened mortar - with admixtures																				
a. Compressive strength BS 4551: 1980																				
b. Shrinkage BS 1881: 1970																				
vi. Testing mortars on site																				
vii. Further investigations																				
viii. Report Writing																				

	Wk 1					Wk 2					Wk 3					Wk 4					Wk 5					Wk 6					Wk 7					Wk 8				
	D1	D2	D3	D4	D5	D1	D2	D3	D4	D5	D1	D2	D3	D4	D5	D1	D2	D3	D4	D5	D1	D2	D3	D4	D5	D1	D2	D3	D4	D5	D1	D2	D3	D4	D5	D1	D2	D3	D4	D5
iv. Characteristics of fresh mortar - with admixtures																																								
Sand 1- *mix B, % retarder fixed, % air varied from 6 to 18 %*																																								
→ optimum % of air																																								
a. Flow BS 4551: 1980																																								
b. Consistency BS 4551: 1980																																								
c. Water retentivity BS 4551: 1980																																								
d. Air content BS 4551: 1980																																								
e. Plastic density BS 4551: 1980																																								
v. Characteristics of hardened mortar - with admixtures																																								
a. Compressive strength BS 4551: 1980																																								
iv. Characteristics of fresh mortar - with admixtures																																								
Sand 2- *mix E, % retarder fixed, % air varied from 6 to 18 %*																																								
→ optimum % of air																																								
a. Flow BS 4551: 1980																																								
b. Consistency BS 4551: 1980																																								
c. Water retentivity BS 4551: 1980																																								
d. Air content BS 4551: 1980																																								
e. Plastic density BS 4551: 1980																																								
v. Characteristics of hardened mortar - with admixtures																																								
a. Compressive strength BS 4551: 1980																																								
iv. Characteristics of fresh mortar - with admixtures																																								
Sand 1- *% retarder fixed, % air fixed, mix varied (A, B, C, D)*																																								
→ optimum mix for Sand 1																																								
a. Flow BS 4551: 1980																																								
b. Consistency BS 4551: 1980																																								
c. Water retentivity BS 4551: 1980																																								
d. Air content BS 4551: 1980																																								
e. Plastic density BS 4551: 1980																																								

v. Characteristics of hardened mortar - with admixtures	
a. Compressive strength	BS 4551: 1980
b. Shrinkage	BS 1881: 1970
iv. Characteristics of fresh mortar - with admixtures	
Sand 2- *% retarder fixed, % air fixed, mix varied (E, F, G, H)*	
→ optimum mix for Sand 2	
a. Flow	BS 4551: 1980
b. Consistency	BS 4551: 1980
c. Water retentivity	BS 4551: 1980
d. Air content	BS 4551: 1980
e. Plastic density	BS 4551: 1980
v. Characteristics of hardened mortar - with admixtures	
a. Compressive strength	BS 4551: 1980
b. Shrinkage	BS 1881: 1970

Sieve (mm)	BS 1199 LIMITS (%) Type B		% Passing		
			SAND 1	SAND 2	LAGOON SAND
0.075	0	5	2	22	2
0.15	0	20	20	32	4
0.30	5	75	63	44	13
0.60	55	100	88	59	62
1.18	70	100	95	76	79
2.36	80	100	99	99	92
5.00	95	100	100	100	100
6.30	100	100	100	100	100



FOSROC

Conplast AE300

Air entraining admixture

Uses

- To produce air entrained concrete for increased durability and resistance to damage by frost and de-icing salts. Typical applications include concrete roads and bridge decks, airport runways and taxiways and other extensive areas of concrete exposed to potential frost damage.
- To improve cohesion and workability of concrete mixes where poorly graded aggregates must be used and bleeding, segregation or sand runs occur
- As part of a combined admixture system for the production of ready mixed retarded mortar

Advantages

- Air entrainment increases the resistance of concrete to attack by frost and de-icing salts, reducing problems of surface scaling and concrete failure
- Entrained air bubbles assist in the formation of a stable cohesive mix, reducing segregation and bleeding
- Air entrainment improves workability and helps produce a dense, uniform, close textured surface free from gravel nests and sand runs, so further enhancing durability
- Excellent air bubble stability allows use with a wide range of aggregate qualities and mix conditions

Standards compliance

Conplast AE300 complies with BS 5075 Part 2, BS 4887 Part 1, ASTM C260 and with the Department of Transport Specification for Highway Works.

Description

Conplast AE300 is a chloride free water reducing admixture based on neutralised vinsol resin. It is supplied as a brown solution which instantly disperses is water.

Conplast AE300 acts at the interface between the mixing water and cement/aggregate particles to produce microscopic air bubbles, which are evenly distributed throughout the concrete. The entrained air enhances durability by providing protection against the rapid

Technical support

Fosroc provides a technical advisory service for on-site assistance and advise on admixture selection, evaluation trials and dispensing equipment. Technical data and guidance can be provided for admixtures and other products for use with fresh and hardened concrete.

Typical dosage

The optimum dosage for Conplast AE300 to meet specific requirements should always be determined by trials using the materials and conditions that will be experienced in use. This allows the optimisation of admixture dosage and mix design and provides a complete assessment of the concrete mix.

A starting point for such trials a dosage of 0.08 litres/ 100 kg of cement will typically give an air content of 5% ±1.5% in a medium workability concrete of 300 - 350 kg / m³ cementitious content. Where cement replacement materials are used they should be included in the cementitious content for purposes of calculating admixture dosage. The presence of PFA or microsilica may increase the dosage required to obtain a particular air content. Further details of typical dosage levels are given later in this data sheet.

Use at other dosages

Dosages outside the typical ranges suggested on this sheet may be used if necessary and suitable to meet particular mix requirements, provided that adequate supervision is available. Compliance with requirements must be assessed through trial mixes. Contact the Fosroc Technical Service Department for advice in these cases.

Properties

Appearance:	Brown liquid
Specific gravity:	Typically 1.02 at 20°C
Chloride content:	Nil to BS 5075
Alkali content:	Typically less than 14.0 g. Na_2O equivalent/litre of admixture. A fact sheet on this subject is available

FOSROC

Instructions for use

Checking and control

Once a suitable dosage has been selected, care should be taken to ensure consistency of materials used and mixing and delivery procedures. Air content should be checked regularly by such means as the pressure method described in BS 1881 and ASTM C231.

Factors affecting air entrainment

A number of factors can affect the air entrainment obtained for a particular dosage of air entraining admixture, some of which are listed below. The examples given of changes that these factors may make to a concrete mix should be taken as guidelines only and the actual effects in any particular situation confirmed in trials.

a) Sands of apparently the same grading may have significantly different effects on the level of air entrainment, depending on factors such as silt content, particle size distribution and particle shape. Where changes in sand source or content must be made, or where sans varies within the same source, a careful check must be made on the effects on air entrainment.
b) Increased cement fineness will tend to increase air entrainment. Increased cement content will tend to decrease air content. Changes in cement source and type may also lead to changes in the admixture dosage required to obtain a particular air content.
c) The presence of carbon or organic impurities may reduce the effectiveness of an air entrainer and require an increased dosage. This will not usually be a problem but care may be required when using PFA, certain pigments or lignite bearing sands.
d) Increased concrete temperature will tend to reduce air entrainment. Typically a rise from 10°C to 32°C may halve the level of air. In normal mixing conditions daily fluctuations will not give significant variations.
e) Variations of mixer type and transit time may change the level of air entrainment. Small losses may occur during pumping. These will generally be consistent for a given set of conditions. High air contents may significantly reduce pump efficiency over long pump distances.
f) Normal compacting procedures will not affect air entrainment. Prolonged vibration should be avoided.
g) Increased dosages may be required at low workability

Compatibility

Conplast AE300 is compatible with other Fosroc admixtures in the same concrete mix. All admixtures should be added to the concrete separately and must not be mixed together prior to addition. The performance of concrete containing more than one admixture should be assessed by the trial mix procedure recommended on this data sheet.

Conplast AE300 is suitable for use with all types of ordinary Portland cement. Contact the Fosroc Technical Service Department for advice on use with special cements and blends containing cement replacement materials.

Dispensing

The correct quantity on Conplast AE300 should be measured by means of a recommended dispenser. The admixture should then be added to the concrete with the mixing water to obtain the best results. Contact the Fosroc Technical Service Department for advice regarding suitable equipment and its installation.

Effects of overdosing

An overdose of double the intended amount of Conplast AE300 will result in a significant increase in air entrainment, which will reduce strength. The degree of this effect will depend on the particular mix design and overdose level.

Increased air content from an overdose will tend to have an increased plasticising effect. Some slight increase in setting time may also occur.

Curing

As with all structural concrete, good curing practice should be maintained. Water spray, wet hessian or a Concure* spray applied curing membrane should be used.

Typical performance examples

Many variables in concreting materials and conditions can affect the selection and use of an admixture. Trials should be made using relevant materials and conditions to determine the optimum mix design and admixture dosage to meet specific requirements.

Typical performance examples from evaluation studies of Conplast AE300 are included on this data sheet. The values quoted are representative of results obtained and are provided as illustrations of performance in different situations. Because of the variability of concreting materials, the results only be taken as typical of the performance to be expected. Results quoted in individual examples should not be taken as necessarily directly comparable with other examples given here or results obtained elsewhere for Conplast AE300 or other products.

Unless otherwise specified, all testing was carried out to the relevant parts of applicable British Standards.

Figure 1: Typical dosage on Conplast AE300 to give a range of air contents

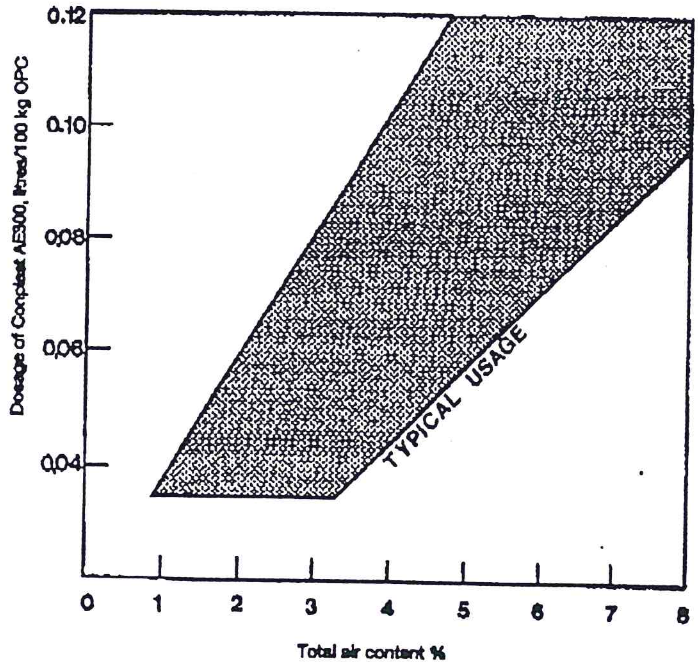
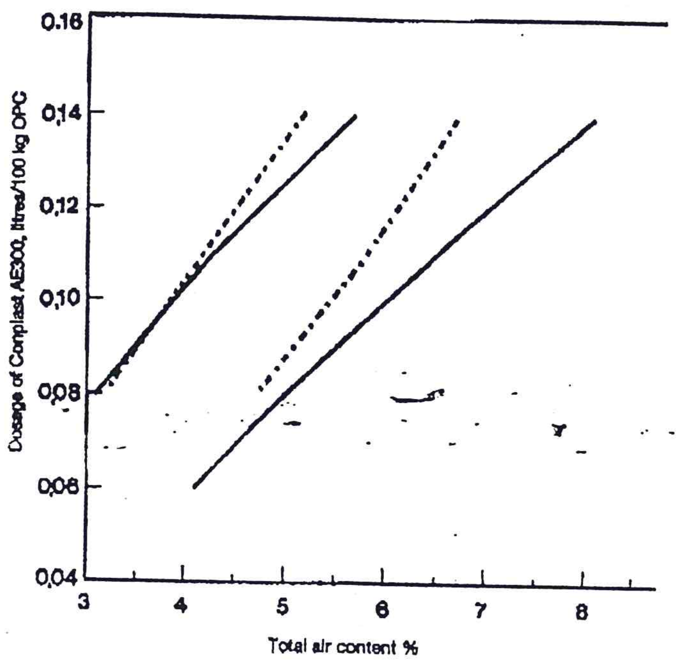


Figure 1 shows the range of air contents that are typically obtained at particular dosages of Conplast AE300 over a range of mix conditions and variables. Particular combinations mav give results outside the indicated area.

Figure 2: Example of variability of air content caused by particular aggregate and cement source variations



The lines on Figure 2 are paired, the solid lines show results from the particular aggregate source and the dashed lines from a different source. In each pair, the upper line and lower line show the effect of two different cement sources. These results relate specifically to the aggregate and cement sources used in the example, other sources and mix design are likely to give different results

Limitations

Some cement replacement materials, particularly low grade PFA, may lead to a significant increase in the dosage of Conplast AE300 required to produce a desired air content. In such situations the use of an air entrainer based on synthetic surfactants, such as Conplast AE316*, is recommended.

Estimating - packaging

Conplast AE300 is available in drum and bulk supply. For larger users, storage tanks can be supplied. Details of specific packaging volumes are available on request.

FOSROC

UN packaging regulations

To comply with current regulations, all products of a hazardous nature which are subjected to a sea crossing as part of their delivery requirements, must be packed in UN approved receptacles.

When a known sea crossing is involved, Fosroc will supply in the correct UN packaging. Where Fosroc are requested to deliver within the South African mainland, but the Purchaser intends to ship on, it is incumbent upon the Purchaser to specify that UN packaging is required at the time of placing the order. Otherwise, once received, responsibility rests with the Purchaser.

The use of UN packaging may affect the selling price of products. Refer to the local Fosroc office or representative.

Storage

Conplast AE300 has a minimum shelf life of 12 months provided the temperature is kept within the range of 2°C to [illegible]°C. Should the temperature of the product fall outside this range then the Fosroc Technical Service Department should be contacted for advice.

Freezing point: Approximately 0°C.

Precautions

Health and safety

Conplast AE300 is alkaline and an irritant and should not be swallowed or allowed to come into contact with skin and eyes.

Suitable protective gloves and goggles should be worn.

Splashes on the skin should be removed with water. In case of contact with eyes rinse immediately with plenty of water and seek medical advise. If swallowed, seek medical attention immediately - **do not** induce vomiting.

For further information consult the Material Safety Data Sheet available for this product.

Fire

Conplast AE300 is water based and non-flammable.

Cleaning and disposal

Spillages of Conplast AE300 should be absorbed onto sand, earth or vermiculite and transferred to suitable containers. Remnants should be hosed down with large quantities of water.

The disposal of excess or waste material should be carried out in accordance with local legislation under the guidance of the local waste regulatory authority.

Additoinal information

Conplast AE300 was previously known as Conplast AEA.

*See separate data sheet.

FOSROC

Fosroc (Pty) Ltd
Reg No. 75/01808/07

14 Bosworth Street
Alrode 1450
P O Box 123910
Alrode 1451
Tel: (011) 908-1960/6
Fax: (011) 908-2749

Important note

Fosroc products are guaranteed against defective materials and manufacture and are sold subject to its standard terms and conditions of sale, copies of which may be obtained on request. Whilst Fosroc endeavours to ensure that any advice, recommendation, specification or information it may give is accurate

Cebex 305

Retarding admixture for mortar

Uses

- Used in conjunction with Cebex or Conplast air entrainers* to produce a pre-mixed retarded mortar with a usable life of typically up to two working days
- To provide controlled extension of working life for pre-mixed renders or screeds

Advantages

- Controlled retardation allows extended working life to be obtained
- Allows pre-mixing of mortar in large volumes for gradual use, increasing quality and consistency of the supplied material
- Pre-mixing of large volumes of mortar allows more accurate and consistent dispensing of colour pigments
- In combination with Cebex or Conplast air entrainers provides air entrainment and reduced water content to the mix which decrease water absorption and enhances durability
- Can reduce or eliminate the need to use lime when used in combination with Cebex or Conplast air entrainers

Standards compliance

Cebex 305 complies with BS 4887 Part 2 as a retarding admixture for mortar and with the requirements of BS 4721, Specification for ready-mixed building mortars, Section 3.

Description

Cebex 305 is a chloride free plasticising and retarding admixture based on selected hydroxycarboxylic materials. It is supplied as a straw coloured solution which instantly disperses in water.

Cebex 305 enhances the dispersion of the cement particles in a mortar mix, exposing a greater surface area of cement to the mixing water and enabling the water content of the mortar to perform more effectively.

The initial hydration of the cement is also delayed. By careful selection of dosage level and combination with Cebex or Conplast air entraining agents, this can be used to extend the working life of a pre-mixed mortar to a level suitable for the particular bricks or blocks that are to be laid. Once between the bricks or blocks, water is drawn from the mortar. This causes acceleration of the stiffening and the mortar then sets and performs in a similar manner to conventional non-retarded mortars.

Technical support

Forsoc provides a technical advisory service for on-site assistance and advice on admixture selection, evaluation trials and dispensing equipment. Technical data and guidance can be provided for admixtures and other products for use with fresh and hardened concrete.

Typical dosages

The optimum dosage of Cebex 305 to meet specific requirements must always be determined by trials using the materials and conditions that will be experienced in use. This allows the optimisation of admixture dosage and mix design and provides a complete assessment of the concrete mix.

Typical dosage levels for Cebex 305 for use in retarded mortars lie in the range of 0.30 to 1.60 litres/100 kg of cement. The actual level will depend on the working life required and other factors such as the type of sand used. A dosage selection method is detailed later on this sheet.

Where lime is used in the mix the admixture should be dosed based on the total amount of lime and cement in the mix. The recommended trial procedure will allow the effects of lime to be determined. An initial starting point for trials is to consider the lime to have the same admixture demand as three times its own weight of cement.

Use at other dosages

Dosages outside the typical range suggested on this sheet may be used if necessary and suitable to meet particular mix requirements, provided that adequate supervision is available. Compliance with requirements must be assessed through trial mixes. Contact the Fosroc Technical Service Department for advice in these cases.

Properties

Appearance:	Straw coloured liquid
Specific gravity:	Typically 1.17 at 20°C
Chloride content:	Nil to BS 4887

SROC

structions for use

: design

pical mortar mixes based on BS 4721 Section 3 are wn in table 1, together with typical performance cifications associated with them. These specifications used throughout the United Kingdom and, in the sence of suitable alternatives, can be employed as a ful guide on a worldwide basis.

mprehensive trial mixes with local materials should be formed to ensure suitable performance is obtained and the optimum dosages of Cebex 305 and other Fosroc xtures are selected. In particular the silt content of the used will have a large effect on the dosage of Cebex required. Low silt contents will require lower dosages Cebex 305 and high silt contents will require higher ages. However, silt does help to promote mix cohesion reduce bleed water in the mortar.

entrainment

t specifications for mortar require entrained air to be uded. The inclusion of adequate quantities of air is essary to allow satisfactory workability and ease of use e maintained. The use of Cebex or Conplast air rainers is recommended.

use of air entrainment also reduces segregation and ding, should these faults be apparent. If these blems are severe then contact the Fosroc Technical ice Department for advice on the selection of ative sands and other potential admixture nations.

age selection

dosage of Cebex 305 to be used in initial trials should elected as follows, the results of trials should then be to determine the actual dosage required to give the perties desired.

he mortar constituents should be chosen to meet any pecified requirements for mix proportions, cement and air content. A target retardation period should then be hosen. This will typically be to provide two working ays in which the mortar is of a usable workability. However, where masonry units with low absorption alues are to be used, or retardation of renders and creeds is desired, it is recommended that a maximum etardation period of one working day is used.

he appropriate starting trial dosage for the desired eriod of retardation is selected from Figure 1. For example, a dosage of 1.0 litres/100 kg of cement would e chosen as the starting point for trials to produce 30

Table 1: BS 4721, Specification for Retarded Mortars

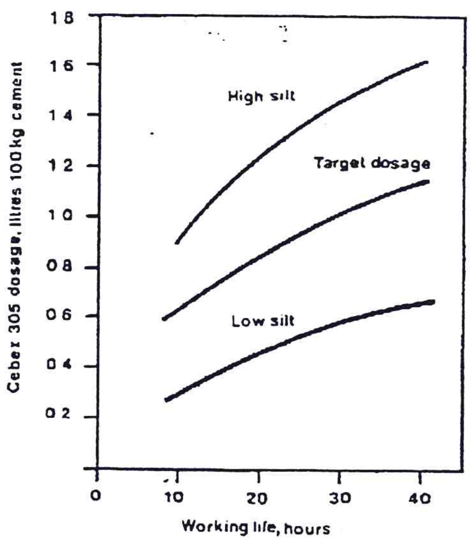
a) Mix proportions

Mortar Designation	Cement/sand volume proportions	Cement content % by weight
i	1:3	20.5 to 25
ii	1:3 to 1:4	16.0 to 25.0
iii	1:5 to 1:6	11.5 to 16.5
iv	1:7 to 1:8	8.5 to 12.5

b) Specified properties

Mortar	Minimum 28 day Comp. strength MPa	Minimum Water retentivity %	Maximum Flow %	Entrained Air %
i	11.0	88	135	7 to 12
ii	4.5	89	130	7 to 12
iii	2.5	90	125	7 to 15
iv	1.0	91	125	7 to 15

Figure 1: Typical relationship between workable life and dosage at constant water content for different types of sand



3. A trial mix should then be produced using the intended materials and the actual retardation time obtained should be recorded. A number of factors will affect the level of retardation obtained, including moisture content of the sand, silt content in the sand, initial mortar workability, and cement chemistry. If the desired retardation is not obtained then comparison of the actual working life for the starting dosage used with the curves provided on Figure 1 will allow a modified dosage to be selected for further trials.

4. Once a suitable dosage has been selected by the trial procedure, care should be taken to ensure consistency of materials used and mixing and delivery procedures. Air contents and initial delivered workability should be checked regularly.

Mix workability

The initial workability of a retarded mortar is an important factor in ensuring a consistent product with the desired workability retention characteristics. The initial workability should be within the range of 100 to 110% as measured using the BS 4551 flow table.

Storage of mixed mortar

Once manufactured, the mixed mortar must be protected from moisture loss. It is recommended that mortar is stored in a non-porous container with a close fitting lid. If evaporation occurs, the mortar will prematurely form a crust.

Compatibility

Cebex 305 is compatible with other Fosroc admixtures used in the same mortar mix. All admixtures should be added to the concrete separately and must not be mixed together prior to addition. The resultant properties of mortar containing more than one admixture should be assessed by the trial mix procedure recommended on this data sheet.

Cebex 305 is suitable for use with all types of ordinary Portland cement. Contact the Fosroc Technical Service Department for advice on use with special cements and blends containing cement replacement materials.

Dispensing

The correct quantity of Cebex 305 should be measured by means of a recommended dispenser. The admixture should then be added to the concrete with the mixing water to obtain the best results. Contact the Fosroc Technical Service Department for advice regarding suitable equipment and its installation.

When a Cebex or Conplast air entrainer is to be added to the mix, it must be added via a separate dispenser or a purpose build multi-dispenser unit.

Effect of overdosing

An overdose of double the intended amount of Cebex 305 will result in a significant increase in retardation as compared to that normally obtained at the intended dosage. An overdose will also tend to increase the plasticising effect of the admixture. The degree of these effects will depend on the particular mix design and overdose level.

Curing

As with all cementitious systems, good curing practice should be maintained. Curing is particularly important when retarded screeds or renders are used.

Typical performance examples

Many variables in concreting materials and conditions can affect the selection and use of an admixture. Trials should be made using relevant materials and conditions in order to determine the optimum mix design and admixture dosage to meet specific requirements.

Typical performance examples from evaluation studies of Cebex 305, are included on this data sheet. The values quoted are representative of results obtained and are provided as illustrations of the performance in different situations. Because of the variability of concreting materials, the results should only be taken as typical of the performance to be expected. Results quoted in individual examples should not be taken as necessarily directly comparable with other examples given here or results obtained elsewhere for Cebex 305 or other products.

Unless otherwise specified, all testing was carried out to the relevant parts of applicable British Standards.

Table 2: Comparison of performance of retarded mixes with Cebex 305 and non-retarded mixes containing lime.

Mortar Designation	Mortar type	Compressuve strength MPa to BS 4551		ISAT absorption value, BS 1881 ml/m²/second		%improvement	
		28 day	specification	10 min	30 min	10 min	30 min
Class ii	cement:lime	9.0	4.5	2.14	1.44	-	-
	Cebex 305	9.0	4.5	0.65	0.48	70	70
Class iii	cement:lime	3.5	2.5	6.0	3.6	-	-
	Cebex 305	3.0	2.5	4.0	2.5	30	30

SROC

nitations

e recommendations on this data sheet concerning the ximum working life to be used with low absorption asonry units and retarded screeds and renders should carefully followed.

stimating - packaging

bex 305 is available in drum and bulk supply. For larger rs, storage tanks can be supplied. Details of specific ckaging volumes are available on request.

packaging regulations

omply with current regulations, all products of a ardous nature that are involved in a sea crossing as . of the delivery requirements must be packed in United tions Approved receptacles.

en a known sea crossing is involved Fosroc will supply ne correct UN packaging. Where Fosroc are only uested to deliver within the South African mainland, but purchaser intends to ship on, it is incumbent on the chaser to specify that UN packaging is required at the e of placing the order. Otherwise, once delivery is ived, the responsibility is that of the purchaser.

e use of UN packaging may affect the selling price of ducts. Refer to the local Fosroc office or representative.

orage

ex 305 has a minimum shelf life of 12 months provided mperature is kept within the range of 2°C to 50°C ould the temperature of the product fall outside this e then the Fosroc Technical Service Department ld be contacted for advice.

Precautions

Health and safety

Cebex 305 does not fall into the hazard classifications of current regulations (see notes 1 and 2 below). However, it is mildly alkaline and should not be swallowed or allowed to come into contact with skin and eyes.

Suitable protective gloves and goggles should be worn.

Splashes on the skin should be removed with water. In case of contact with eyes rinse immediately with plenty of water and seek medical advice. If swallowed seek medical attention immediately - **do not** induce vomiting.

For further information consult the Material Safety Data Sheet available for this product

Fire

Cebex 305 is water based and non-flammable.

Cleaning and disposal

Spillages of Cebex 305 should be absorbed onto sand, earth or vermiculite and transferred to suitable containers. Remnants should be hosed down with large quantities of water.

The disposal of excess or waste material should be carried out in accordance with local legislation under the guidance of the local waste regulatory authority.

Additional Information

Note 1: CPL Regulations 1984 Supply-Schedule 1

Note 2: HSE publication Guidance Note EH40

*See separate data sheet

SROC

Fosroc (Pty) Ltd
Reg No. 75/01808/07

14 Bosworth Street
Alrode 1450
P O Box 123910
Alrode 1451
Tel: (011) 908-1980/6
Fax: (011) 908-2749

portant note