Seminar on

Alternatives to River Sand

Organized by the

Research Committee on Geology & Mineral Resources of the National Science Foundation

Sponsored by

The Coastal Resources Management Project of the Ministry of Fisheries and Ocean Resources

26th September 2003
NSF Auditorium

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Date: 26th September 2003 Venue: NSF Auditorium

PROGRAMME

08.30 a.m.	**Registration of Participants**
09.00 a.m.	**Welcome address** Director National Science Foundation
09.10 a.m.	**Introduction to the seminar** Mr Priyalal Dias Chairman/ Research Committee on Geology & Mineral Resources of the National Science Foundation
	Status of sand supply
09.20 a.m.	**Resource base and the government policy** Mr Athula Mudunkotuwa Deputy Director - Geology Geological Survey & Mines Bureau
09.40 a.m.	**Discussion**
	Alternatives for river sand
09.55 a.m.	**Offshore sand** Prof. Priyan Dias Dept. of Civil Engineering University of Moratuwa
10.15 a.m.	**Manufactured sand** Dr Athula Senaratne Head/ Dept. of Geology University of Peradeniya
10.35 a.m.	**Discussion**
10.50 a.m.	T E A

Environmental and social aspects

11.10 a..m.	**Environmental and social aspects of river sand and dune sand mining** Mr Anil Pieris Deputy Director - Mines Geological Survey & Mines Bureau
11.30 a.m.	**Mitigatory measures to prevent coastal erosion** Prof. Samantha Hettiarachchi Dept. of Civil Engineering University of Moratuwa
11.50 a.m.	**Discussion**

Application of alternative materials

12.05 p.m.	**Engineering properties of river sand alternatives** Dr Anura Nanayakkara Dept. of Civil Engineering University of Moratuwa
12.25 p.m.	**Evaluation of quality related factors for building construction** Ms N.K. Muthurathne Scientist National Building Research Organization
12.45 p.m.	**Economics of river sand alternatives** Dr Asoka Perera Dept. of Civil Engineering University of Moratuwa
01.05 p.m.	**Discussion**
01.20 p.m.	LUNCH

Response from construction industry

02.20 p.m.	**Problems faced by the construction industry** Mr Viraj Dias Central Engineering Consultancy Bureau Mr D.W. Balachandra Chief Executive Officer National Construction Association of Sri Lanka
02.50 p.m.	**General discussion** Moderator : Mr C.H. de Tissera
03.20 p.m.	**Summing up** Mr C.H. de Tissera
03.30 p.m.	Close of workshop

Rapporteurs : Mr Asoka de Silva
Mr Jayantha Ranatunga
Prof. P.G.R. Dharmaratne

Resource Base & Government Policy

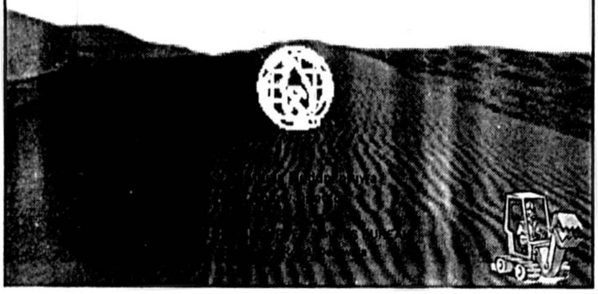
Athula Mudunkotuwa

The river sand still remains the main source of sand for construction industry in Sri Lanka. The demand for sand has been ever increasing with the development of building industry. As a result, it has been noticed the over exploitation of river sand causing serious environmental problems. At least during the past five years, this problem has been discussed at various fora by the concerned scientists and engineers. One of the main objectives of these discussions was the identification of potential sources of river sand alternatives. The land based sand, quarry dust and offshore sand are now being recognized as river sand alternatives and more recently the concept of manufactured sand has been introduced.

A proper identification of sustainably exploitable volumes of sand from at least major rivers is still lacking. However, some serious attempts have been made by GSMB to identify the exploitable sand reserves of Deduru Oya by conducting three consecutive surveys in 1999, 2001 and 2003. The information on the deposits were provided to relevant Divisional Secretaries enabling them to sell the deposits by tender and thus effectively controle the mining activities in Deduru Oya and allow the proper implementation of mining regulations under Mines & Minerals Act # 33 of 1992.

All river sand miners should possess valid licences issued by the Geological Survey & Mines Bureau and the Divisional Secretary of the relevant area. It has been observed a positive tendancy towards harnessing offshore sand in the recent past. Within past three years seabed mining has been done to supply large volumes of sand (nearly 7 million m^3) required for the large scale projects. However, for offshore sand mining it is mandatory to conduct an Environmental Impact Assessment. A mining licence is issued only if environmental clearence is obtained. As a result of the escalated prices of river sand, the offshore sand is now becoming an competitive alternative. As all minerals belong to the state a royalty is charged for sand at the rate of 1% of the value of the mined out put.

SAND MINING & REGULATORY FRAME WORK



Is sand a mineral?

- What is a mineral

According to Mines and Mineral Act
33 of 1992
(From page 32)

"mineral. Means a naturally occurring substance that can be mined , whether in solid, liquid or gaseous form, in or below the surface of the soil;any ores containing such minerals and any product of such minerals derived by processing and includes peat and salt but does not include hydro-carbons

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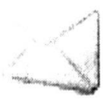
❖ Therefore a valid licence must be obtained for sand mining from GSMB



Although a licence is issued by the GSMB, the licence holder would not be able to mine without the consent of the land owner

- According to clauses 51 and 52 of the Act,

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51. The holder of a licence issued under this Act shall have the right to enter and possess any area of land specified in such license;

Provided that where the owner of any such area of land is in possession of such area of land the holder of the licence shall not exercise the rights conferred on him by this section except with the consent of such owner

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52. (I) The holder of a licence issued under this Act shall avoid interference with the owner or occupier of the land specified in his licence or the holder of any other licence in respect of such land and avoid damage to their personal property

(II) The holder of a licence issued under this Act shall on the completion of the activities authorized by his licence or on the date of expiration of his licence whichever occurs earlier rehabilitate the land to the satisfaction of the Bureau

(III) Where the Bureau determines that the land has not been rehabilitated to a satisfactory condition the holder shall be liable to the payment of compensation to the owner of the land in such amount as may be determined by the Bureau in the prescribed manner

- According to the land and forest ordinances all water bodies belong to the State. When mining is carried out at such places, the miner should obtain the permission of the Divisional Secretary or the Conservator of Forest as the respective authorities for land.

- Therefore, when sand is mined from rivers or streams the miner should possess two valid licences obtained from
  1. GSMB
  2. Div. Sec. or Con. of Forest

  If one of these licences is cancelled the other one will also seized to be valid

As stated above, the GSMB and Divisional Secretary or Conservator of Forest are equally empowered to authorize for sand mining in water bodies.

- Therefore, the persons engaged in sand mining in such locations should pay two royalties

  * Royalty for extraction of sand
    - to GSMB

  * Royalty for land use
    - to Div. Sec or Conse. of Forest

The GSMB follows the following procedure in processing of each application lodged at a GSMB office for sand mining

❖ Requests for a report and recommendations of the relevant Div. Secretary required to be obtained as per the Mining & mineral Act # 33 of 1992.

Without the proper recommendation of the Div. Secretary, the Bureau dose not issue licences.

❖ A mining engineer of GSMB inspect the site and submit a technical report in this regard

A licence for sand mining is issued only if both the Div. Secretary and the mining engineer recommend in favour of issuing a licence.

A copy of the licence issued by the GSMB is send to the Div. Secretary for his information.

Sand Mining Licenses, 2003

	RIVER	# OF AL/A	# OF AL/B	TOTAL # OF LICENCES	DISTRICT	DIVISIONAL SEC. AREAS
1	Kelani Ganga	21	54	75	Kegalle (73) Colombo (1)	Yatiyantota (19) Dehiowita (26) Ruwanwella (28) Colombo (1)
2	Gin Ganga	02	50	52	Galle (52)	Weliwitiya Divitura (8), Baddegama (38), Neluwa (4) Galle (1) Tawalama (1)
3	Kalu Ganga	02	104	106	Ratnapura (11) Kalutara (111)	Kiriella (28), Ayagama (7), Ratnapura (9) Millaniya (27), Bulathsinghala (9), Dodangoda (4) Madurawala (30), Ingiriya (34)
4	Walawe Ganga	28	35	63	Ratnapura (18) Monaragala (6) Hambantota (11)	Ambilipitiya (37), Balangoda (5), Imbulpe (1) Sevanagala (6) Suriyawewa (7), Ambalantota (7)
5	Ma Oya	07	38	45	Kegalle (30) Kurunegala (15)	Rambukkana (22), Galigamuwa (2), Warakapola (6), Polgahawela (4), Divulapitiya (2) Pannala (1) Alawwa (8)
6	Mahaweli Ganga	13	25	38	Trincomalee (18) Polonnaruwa (12) Badulla (8)	Seruwila (16), Kantale (2) Dimbulagala (12) Kandaketiya (6), Mahiyangana (2)
7	Menik Ganga	09	06	15	Monaragala (15)	Buttala (4), Kataragama (11)
8	Deduru Oya	19	10	29	Kurunegala (15) Puttalam (4)	Wariyapola (15) Puttalam (4)
8	Bentota Ganga	-	36	36	Kalutara (32) Galle (4)	Walliwita (32) Elpitiya (4)
9	Kirindi Oya	-	06	06	Hambantota (5) Monaragala (1)	Tissamaharama (4) Lunugamvehera (1) Badalkumbura (1)
	TOTAL	101	444	545		

Types of Licences

– issued for sand mining

A. Rivers

Artisanal Mining License

AML/A. (100<monthly product<600 m^3)

AML/B. (100m^3 <monthly product)

This licence is valid for one year and not transferable

B. Offshore

IML/A. Industrial Mining License

(monthly product > 1500 m^3)

The validity period is determined by the Bureau

Collection of Royalty

- For the purpose of collection of royalties sand is considered as a "building material"
- Therefore, royalty for sand is 1% from sales or determined market value of mine output
- According to regulations "building materials" include brick, tile & cement clay, sand, gravel, laterite, limestone ,dolomite, marble, shale, stone, aggregate & dimension stone

Sources of sand and sand alternatives

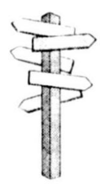
1. River Sand

   Land based sand (dunes, sand deposited in ancient river courses)

   Quarry dust (byproduct of metal crushing plants)

   Offshore sand

   Manufactured sand (rocks crushed to the required size)



Offshore Mining for Sand (sea sand)

The clause 65(2) of Mines and Mineral Act # 33 of 1992, "Restriction on the power to mine the sea bed" says the following

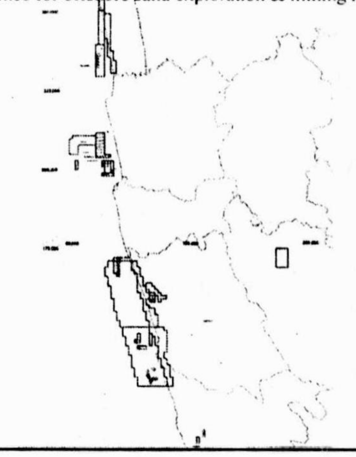
"No person other than a person holding a licence in that behalf issued under the Mining and Minerals Act No 33 of 1992, shall mine the sea bed".

Also, according to the regulation gazetted under the National Environmental Act

Offshore mining is listed as a prescribed project and therefore it requires the project proponent to conduct a proper exploration programme and submit an Environmental Impact Assessment report. Usually CEA acts as the Project Approving Agency for EIA on offshore sand mining.

A mining licence is issued by GSMB only if the EIA submitted in this regard is approved

Licence for offshore sand exploration & mining map



Offshore Exploration licences

Licence No	Name of Applicant	Area	Date of expiry
EL/108	Sri Lanka Land reclamation & Development Cooperation	35sqkm	18/10/03
EL/109	South Asia Gate way Terminals Pvt.Ltd	7sqkm	18/10/03
EL/110	ADB- CRM project	4sqkm	18/10/03
EL/111	ADB- CRM project	3sqkm	24/10/03
EL/112	Road Development Authority	29sqkm	06/11/03
EL/113	Coast Conservation Department	29sqkm	06/11/03

Offshore Industrial Mining Licences

IML Licences No	Name of Licences	Area	Date of expiry
IML/A/1871	Road Development Authority	600hectares	28/02/03
IML/A/2428	South Asia Gate way Terminals Pvt.Ltd	200hectares	25/10/02
IML/A/3390	Coast Conservation Department	700hectares	13/01/04
IML/A/3391	Coast Conservation Department	400hectares	13/01/04

Production details of IML/A/1871 & IML/A/2428

IML/A/1871

Total volume of mined sand = 5,449,766 m^3

The declared value of sand for 1 m^3 = Rs. 309.50

value of a cube ≈ Rs. 830

IML/A/2428

Total value of mineral sand = 1,520,890 m^3

The declared value of sand for 1 m^3 = US$ 3.00

= Rs. 285

value of a cube ≈ Rs. 770

The river sand still remains the main source of sand for construction industry in Sri Lanka

For the effective control of sand mining in Deduru Oya and Ma Oya sand surveys have been conducted by the GSMB. In Deduru Oya surveys were done in 1999, 2001 & 2003. These sand surveys identified the sand deposits and sustainably exploitable volumes of sand.

Explotable Sand Reserves of Deduru Oya

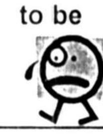
DIVISIONAL SECRETARIAT	# of Identified sand deposits			QUANTITY AVAILABLE IN CUBES		
Year	1999	2001	2003	1999	2001	2003
Pallama	11	08	12	46740	7100	26100
Nikawaratiya	13	08	05	41715	5750	11900
Rasnayakapura	09	10	06	30931	10300	17800
Kobeigane	20	12	11	74490	10500	41000
Ibbagamuwa	08	05	-	2903	1800	-
Chilaw	09	03	04	35212	1100	2100
Arachchikattuwa	11	02	03	34510	1100	2400
Wariyapola	14	05	15	13752	2000	7928
Ridigama	14	09	-	2290	900	-
Ganewatta	08	06	04	4465	2150	1800
Maho	03	03	03	4562	650	1250
Kurunegala	01	01	01	220	50	700
Bingiriya	21	-	09	77621.2	-	13400
TOTAL	142	72	73	372414.2	43400	129378

The necessary information were provided to the relevant Div. Secretaries to sell the deposits by tender.

It is expected that the proper implementation of this practice would bring in better revenue to the State as land rent and royalty charges and minimize the environmental damage.

However, there are certain draw backs in implementing this procedure and extending this to other regions. One of the major draw-backs is the non availability of adequate funds for these surveys.

It has been suggested to keep a revolving fund by allocating a certain amount of money collected from the tendering procedure. But it is yet to be materialized.



Properties of Concrete and Plaster made using Offshore Sand, Manufactured Sand and Quarry Dust

Final Report

(September 2002)

by

Professor W.P.S. Dias

Dr S.M.A. Nanayakkara

G.A.P.S.N. Seneviratne

T. Nanthanan

DEPARTMENT OF CIVIL ENGINEERING

UNIVERSITY OF MORATUWA

Abstract

A literature review and experimental programme were carried out to study certain aspects pertaining to the use of alternatives for river sand in concrete, mortar and plaster, focusing in particular on offshore sand.

The main objectives of the research were (i) to study worldwide experience of using offshore sand in construction; (ii) to test the relevant properties of the aggregates (namely grading for some alternatives and shell and chloride contents for offshore sand); (iii) to design/develop and test mixes for concretes, mortars and plasters; (iv) to ascertain practitioner acceptability in the use of mortars and plasters; and (v) to study the performance properties of efflorescence and corrosion in concrete.

A sand column was fabricated for checking the effects of natural drainage and simulated rain on the chloride levels in offshore sand. Also, special moulds were fabricated to produce corrosion test specimens having low (i.e. 20 mm) covers of concrete made with normal sized (i.e. 20 mm) aggregate. The accelerated corrosion tests were carried out in both a 5% NaCl bath and a carbonation chamber. Half-cell potential measurements were taken to detect corrosion activity.

Offshore sand was found to be better than manufactured sand for concrete. Both offshore sand and manufactured sand were found to be satisfactory for both mortars and plasters and reasonably acceptable to masons. The shell content of offshore sand did not impair the engineering properties of concrete; on the other hand, the shells in excess of 5 mm (which constitute around 2% of the entire sample) could be extracted for sale to lime kilns.

A figure of 0.075% by weight of the sand was arrived at as a conservative limit for allowable Cl^- ion content in offshore sand for OPC based reinforced or metal-embedded concrete. Offshore sand saturated with sea water has a Cl^- content of around 0.3%, whereas if the seawater is gravity drained, it reduces to around the acceptable 0.075%. The action of even 80 mm of rain will reduce Cl^- contents to below acceptable levels, even at the top of a stockpile (which may be subject to evaporation) and the bottom of a (2 m high) stockpile (which may trap sea water by capillary action). The efflorescence and corrosion performance of grade 20 concrete (i.e. the most critical grade) with the allowable Cl^- content in the sand is satisfactory and similar to a chloride free control mix; on the other hand, a mix with 0.3% Cl^- in the sand shows clear evidence of efflorescence and early corrosion.

1. Introduction and Background

This report describes a programme of research carried out by the University of Moratuwa for ANZDEC Limited on the properties of concrete and plaster made using fine aggregate alternatives for river sand. The need for this arises due to the over-exploitation of river sand and its various harmful consequences (National 1992, Dias et al. 1999). Suggestions for various river sand alternatives have also been made (Dias et al. 1999).

The focus of the current research is on offshore sand, which is clearly the most viable of the alternatives for river sand, with respect to availability, ease of extraction, environmental impact and cost (Dias et al. 1999). However two other alternatives were also studied in a limited way, namely manufactured sand and quarry dust. Both these materials are quarry products. While quarry dust is merely a by product from the production of coarse aggregate and tends to be flaky in shape, manufactured sand is actually produced such that a more desirable "rounded cubic" shape is obtained.

Offshore sand is already used in Sri Lanka for road filling. It is also used for construction in other parts of the world. Part of the research effort was directed at gathering information about worldwide experience on offshore sand.

2. Objectives and Strategy

In the above context, the following can be identified as the broad objectives of this research.

1. To study worldwide experience of using offshore sand in construction.
2. To test the relevant properties of the aggregates.
3. To design/develop and test mixes for concretes, mortars and plasters.
4. To ascertain practitioner acceptability in mortars and plasters.
5. To study the performance properties of efflorescence and corrosion in concrete.

For Objective 1, it was sought to obtain information especially on lower grade concretes in warm climates, with particular reference to the effect of chlorides on reinforced concrete. Lower grades are the ones used in Sri Lanka and in which the effect of chlorides on reinforcement corrosion would be more pronounced; warm climates would accelerate corrosion processes.

For Objective 2, grading was considered an important consideration for all aggregates. In addition, the extent of variability in grading was established for offshore sand. The other two important characteristics of offshore sand tested were shell content and chloride content, with extensive testing on the effect of draining and rain water on the chloride content.

For Objective 3, the concrete mixes (of grades 20, 25 and 30) were actually designed to obtain target workabilities (measured by slump) and strengths (at 3, 7 and 28 days). The fine aggregate used for this was offshore sand and manufactured sand; quarry dust was not considered a suitable material for use in concrete. For the mortars and plasters, the mixes used were those specified in the ICTAD specifications (1980), or slight deviations from them that have been established in practice. The fine aggregate used for this was river sand (as a control), offshore sand, manufactured sand and quarry dust. The properties measured were strength and flow.

For Objective 4, masons were consulted to establish practitioner acceptability for both mortars and plasters (made of river sand, offshore sand, manufactured sand and quarry dust).

For Objective 5, the corrosion and efflorescence testing was carried out for the most vulnerable grade 20 concrete.

Table 1 gives an overall picture of the testing strategy.

3. Literature Review

3.1. Use of Sea Sand in Concrete

This literature review will focus on the use of offshore sand in concrete, since offshore sand is arguably the most promising alternative to river sand, as stated before. It is also the alternative that poses the greatest concerns, primarily with respect to its chloride content (known to promote corrosion of reinforcement and suspected of enhancing efflorescence) and shell content (which in early days was suspected of having negative effects on workability and permeability).

Although offshore sand is reportedly used in many countries such as the U.K., Netherlands, India, Seychelles and Singapore, proper documentation regarding its use was found mainly regarding U.K. practice. A distinction must also be made between the use of offshore sand and sand deposits in dry coastal areas. The latter would tend to have very high chloride contents resulting from salt spray and evaporation over long periods of time. In particular, the use of such deposits for concrete construction in the Middle East has led to very early onset of corrosion (Fookes and Higginbottom 1980, Rasheeduzzafar et al. 1985). A study done on Sri Lankan beach sands has also shown fairly high chloride levels in some samples (Chandrakeerthy 1994). The use of sea water for batching or for curing (Rasheeduzzafar et al. 1985, Katwan 2001) would also promote corrosion; such practices should not be resorted to.

In the U.K. around 11% of its aggregate extraction is from offshore sources. In South East England and South Wales, this figure is as high as 30% and 90% respectively (Marine 2002). While much of this aggregate is processed (inclusive of washing), it is largely unprocessed sand (together with land based coarse aggregate) that is used on the West Coast and the Bristol Channel (Gutt and Collins 1987). The use of such aggregate in concrete has not caused any major durability problems in the U.K. during the past 60 years of its use. In fact, chloride related durability problems in the U.K. have largely been due to the use of Calcium chloride as an accelerator (up to a dosage of 0.15% by weight of cement), a practice that had been permitted up to 1977 (Gutt and Collins 1987).

3.2. Permeability, Strength and Efflorescence

Research carried out by Chapman and Roeder (1970) has established that hollow shells in offshore sand get filled with cement paste or mortar, and that their hollowness does not impair either concrete strength or impermeability; their flakiness, which may reduce workability, has also been found to be offset by their smoothness, and also the greater roundedness of the offshore sand itself. BS 882 (1992) does set some limits on the shell content in coarse aggregate, but none whatsoever on that in fine aggregate (see Section 5.2); this is fortuitous because there would not be any easy way of removing shells from marine dredged fine aggregate (Chapman and Roeder 1969). Chandrakeerthy's (1994) results do not indicate any adverse effects on strength or absorption for concretes made with beach sand.

The literature also indicates that efflorescence from moderate chloride levels in concrete and mortar will be less than that from the free limė present in the concrete or mortar anyway (Marine xxxx). Chandrakeerthy (1994) also did not find any efflorescence in concretes made with large chloride ion concentrations of up to 4.44%.by weight of cement.

3.3. Acceptable Chloride Levels

By far the greatest concern with respect to offshore sand is its chloride level, with respect to the enhancement of corrosion. Most codes of practice specify allowable Cl^- limits as percentages by weight of cement. The easiest to measure is the total Cl^- in the concrete mix, and here it must be remembered that Portland Cement itself can have 0.01-0.05% Cl^- (Gutt and Collins 1987).

The most commonly used limit for total chlorides is the 0.4% limit (by weight of cement) specified in BS 5328: Part 1: 1991 for reinforced concrete. It should be noted that the limit for prestressed concrete is 0.1% and that for reinforced concrete in Sulphate-resisting Portland Cement (SRPC) concrete is 0.2%. BS 882: 1992 uses these limits, together with the allowance for chlorides in the cement, to suggest guidelines for maximum Cl^- contents in the total aggregate of 0.01% (by weight of total aggregate) for prestressed concrete and 0.05% for reinforced concrete. We shall hereafter focus mainly on (non SRPC) reinforced concrete, since it is not envisaged that offshore sand will be used in prestressed concrete production or in SRPC reinforced concrete.

It may be prudent however to reduce the above 0.4% to say 0.3% (by weight of cement), because even in the U.K., there is apparently some evidence that levels as low as 0.4% Cl^- can still promote corrosion, albeit in highly carbonated concrete (Gutt and Collins 1987). Furthermore, a study from Iraq, which has a hot environment like in Sri Lanka, has indicated that corrosion could occur at Cl^- levels of even 0.3% (Katwan 2001).

A better index of potential for corrosion is probably the free or water soluble chloride content. ACI 201-1977 gives limits of 0.10% and 0.15% (once again by weight of cement) for reinforced concrete in moist environments with and without exposure to external chlorides respectively; this limit is raised to 1.0% for concrete in dry, above ground conditions. The relationship between total and free chlorides has been found to depend on binder type, except at total chloride contents below 0.3%, where concretes with many binder types have yielded very low free chloride contents of below 0.024% (Kayyali and Haque 1995). This can be seen as another argument for restricting the total chloride content to 0.3%.

An even better index of corrosion would be the Cl^-/OH^- ratio, although this would be difficult to specify. The threshold value for this ratio has been found to decrease as the pore solution pH is increased (Hussain et al. 1996); it is also lower for an internal chloride source compared to an external one (Kayyali and Haque 1995). It must also be appreciated that the threshold Cl^- levels to initiate corrosion will be lower in cements with lower C_3A contents (Hussain et al. 1996), as they have the capacity to bind chlorides into chloroaluminates.

3.4. Chloride Contents in Offshore Sand

The chloride content in offshore sand will depend on the chloride content in sea water and the moisture content in the sand. Sea water has a Cl^- content of 1.98%, although there would be local fluctuations (Chapman and Roeder 1969). The moisture content of the sand after drainage would depend on the grading of the sand. Sands with low D_{50} values and high ultrafine contents would have greater capillary action and retain more moisture. Typical average moisture contents of 4.3% to 10.9% have been reported from the U.K. (Chapman and Roeder 1969), and 8% to 12% from the Netherlands (Boskalis 2002). If a Cl^- content of 2% is assumed for the sea water, the above moisture content figures would translate into Cl^- contents (by weight of sand) of 0.086% to 0.22% for the U.K. and 0.16% to 0.24% for the Netherlands.

The D_{50} value of offshore sand has a significant influence on the above values; an increase of the D_{50} value from 0.15 mm to 0.37 mm has been found to reduce the moisture and hence chloride content by more than half (Boskalis 2002). If moisture is lost from the sand through evaporation as opposed to drainage however, the chloride content will be higher than reflected by 2% of the moisture content. This could occur in hot, dry environments (Gutt and Collins 1987).

4. Materials and Methods

4.1. Tests on Aggregates

The offshore sand samples were obtained from the stockpile at Muthurajawela. A large sample was obtained of sand that appeared to be typical of the dredged material. In addition, smaller samples were obtained of sand that appeared to be of coarse, fine and medium grading. The fine sand was obtained from the top surface of material that had been just dredged and settled; as such it may not be a truly representative sample.

The manufactured sand was obtained from Lanka Quarries Ltd. and the quarry dust and coarse aggregate (a well graded crushed gneissic material of 20 mm maximum aggregate size) from W.A. Perera & Co. Ltd.

The fine aggregate grading tests were carried out as per BS 812: Part 1 (1975). For the offshore sand samples, the shell content was obtained separately for the aggregate fractions greater than and less than 5 mm, using a hand picking method for the former (BS 812: 1975) and dissolving in HCl for the latter (Chapman and Roeder 1969). The shell content was measured for coarse, medium, fine and typical gradings of offshore sand, from a sample size of 1000 g.

4.2. Chloride Content Tests

Chloride content tests were performed to study the chloride content in the offshore sand under various conditions, for example (i) when the sand was saturated with sea water, (ii) after the sea water had drained, and (iii) after various amounts of fresh water had percolated through the sand, in order to simulate the effect of rain. The sea water was obtained from the pump outlet at the Muthurajawela stockpile.

In order to simulate conditions (ii) and (iii) above, a special container, of cross section 250 mm x 600 mm, was fabricated to hold a column of sand around 2 m high. The sand was retained at the bottom of the container on a mesh, which allowed water to drain into a sump, which itself could either be sealed or drained via an outlet valve. The container had 4 openings (that could be plugged and made watertight) at three levels (including the base) so that the sand could be sampled at the top, bottom and third points along the height, called levels A to D. Figure 1 gives an indication of the setup. The container was first filled with offshore sand (typical grading) and sea water; after the sand was fully saturated for over 24 hours, the sump valve was opened so that the sea water would drain freely. After 5 days of draining, samples were taken from the top, bottom and third points (using one of the openings) in order to obtain a chloride profile with depth for the drained condition; another set of samples was taken after 27 days of draining.

Subsequently, fresh water corresponding to a water height of 80 mm over the 250 mm x 600 mm area of container was sprinkled from above, with the valve still open. A third set of samples was taken after 5 days of draining. This sprinkling was repeated with a further 240 mm height of water (to obtain a total of 320 mm of sprinkled water) and once again the final set of samples taken after 5 days of draining. The sprinkling of fresh water was done to study the change in chloride levels after various amounts of rain, with the 80 mm and 320 mm corresponding roughly to the minimum and maximum values of average monthly rainfall for Colombo – see Table 2.

The samples had to be oven dried prior to chloride testing as per BS 1377: Part 3 (1990). Hence both moisture content and chloride contents could be obtained.

4.3. Concrete Mix Properties

Mixes were designed using both offshore sand (medium grading) and manufactured sand to produce concretes of grades 20, 25 and 30 and target slumps of around 120 to 180 mm. The target mean strengths were set at around 10 N/mm^2 higher than the required grades. The mix designs were based on the British Method (Design 1988), using current Sri Lankan experience as a starting point (Dias 1999). A retarding admixture was used as it was envisaged that ready mixed concrete suppliers would be the first to use these new fine aggregate materials being tested. The cement used was Mahaweli Marine Cement, which is commonly used in the ready mixed concrete industry, having fairly high early strength properties. The offshore sand mixes were tested at the laboratories of a ready mixed company, namely Sanken Lanka Ltd., while the manufactured sand mixes were tested at the University of Moratuwa. The average of two readings was taken for slump. Strength was tested at 3, 7 and 28 days, with the average of 3 test cube results being obtained for each age.

4.4. Corrosion and Efflorescence Testing

The offshore sand mix for grade 20 was chosen for corrosion and efflorescence testing, because this is the lowest grade used in practice for structural concrete and it would have the greatest sand content. Hence the greatest effects of both efflorescence and corrosion would be found in grade 20 concrete.

Three levels of chloride were used in these tests. Series 1 corresponded to a level of 0.3% by weight of sand; this would correspond to a situation where the sand was fully saturated with sea water (see Section 5.3 and Table 5). Series 2 had a level of 0.075% by weight of sand: this was arrived at as the allowable percentage of Cl^- in sand (see Section 5.3 and Table 7). Series 3 did not have any chlorides and was the control test. The rationale for choosing the chloride levels in not surprising, therefore, that natural sand particles have a highly polished surface texture. This aids in the workability of the concrete mix by allowing the particles to slide over each other.Therefore, in manufacturing sand from rocks , the following steps have been added to the conventional crushing process.

1. Controlled crushing of the rock to make cubicle grains
2. Cubicle grains emerging from the crushing plant are subjected to maximum grinding and abrasion.
3. Thorough screening removes most of the clay sized particles retaining required gradation

Crushed and ground rock ensures impurity free sand suitable for any purpose where river sand is used. Cubical to semi-cubicle shape of the product facilitates the formation of a dense matrix when concrete is placed. This is of critical importance when the suitability of manufactured sand is assessed for use in concrete.

Manufactured sand from rocks has many advantages over quarry fines. The particle size of quarry fines is far smaller than the smallest particle in manufactured sand. Quarry fines constitute of particles of different shapes inherited from primary minerals where selected rocks contain only mineral quartz which possess one common shape. The present study reveals that how closely resemble the manufactured sand to natural river sand

D. Athula Senaratne

MANUFACTURE OF CONSTRUCTION SAND FROM COMMON ROKS

BY
ATULA SENARATNE, Ph.D.

Current situation in Sri Lanka

Requirement of sand
10 million cu. M

↑

Small suppliers distributed through out the country

↗ ↖

Mining in the river banks | Dredging in the river bottom

Problem ?

Extraction

Replenishment (Sedimentation)

Solution ???

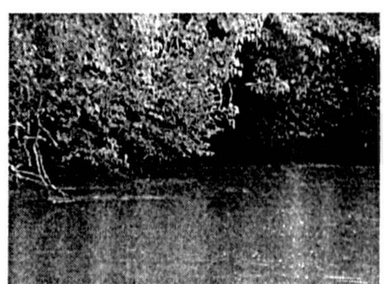
- Reach for buried sand in river meanders and on the river bottom.
- Dredge down to the bed rock

Impacts

- Changing natural flow of rivers
- Change the groundwater regime of the area
- Groundwater contamination

Sand mining in irrigation canals

Lustrous vegetation in stream banks



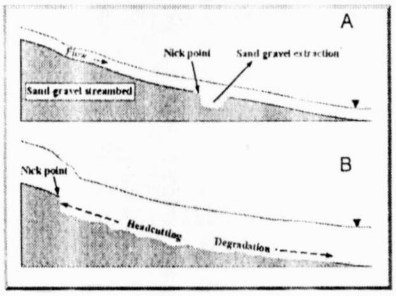


Diagram of sand-and-gravel stream bed showing (A) the nick point that develops with a pit excavation, and (B) the upstream head cutting and downstream bed degradation that develop during high flows.

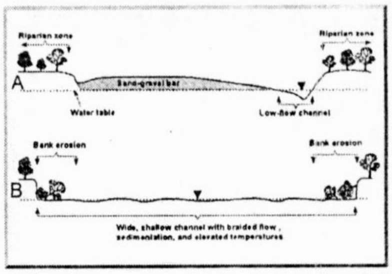
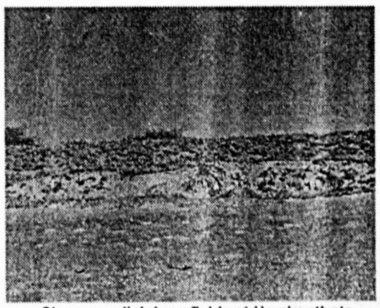


Diagram of channel cross sections showing (A) a typical sand-gravel bar in relation to the low-flow channel, riparian zone and water table, and (B) the wide shallow channel that results from unrestricted mining and that is characterized by bank erosion, braided flow, sedimentation, and increased water temperatures.

Alternative Sand Resources

- Sea Sand
  - On-shore
  - Off-shore
- Manufactured Sand

SEA SAND



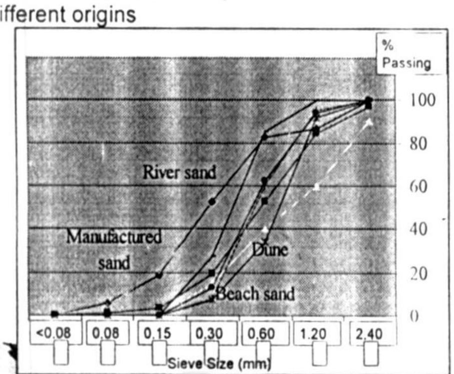
Shore parallel dune fields at Hambanthota

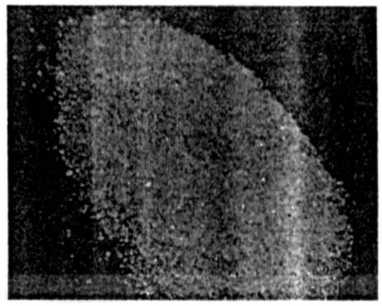
For a final conclusion on the use of sea sand in the construction industry of Sri Lanka, in-depth studies are necessary in the following areas.

- Off-shore reserve estimates
- Detailed characteristics of off-shore sand including mineralogy
- Cleaning process including washing and removal of unwanted minerals
- Energy requirement for pumping
- Environmental impacts.

MANUFACTURED SAND

Manufactured sand compared with sands of different origins





Sand produced in the laboratory . Note clean silica grains with very few or no impurity minerals.

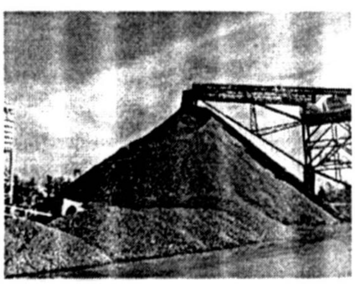
Particle size distribution

U.S. Sieve	3/8"	#4	#8	#16	#30	#50	#100	#200	LBW
Metric Sieve	9.5mm	4.75mm	2.36 mm	1.18 mm	600 µm	300 µm	150 µm	75 µm	-
Typical Particle Size Distribution	100	60-90	20-50	10-30	5-20	5-15	0-5	0-3	0-2

Common Manufactured Sand Products

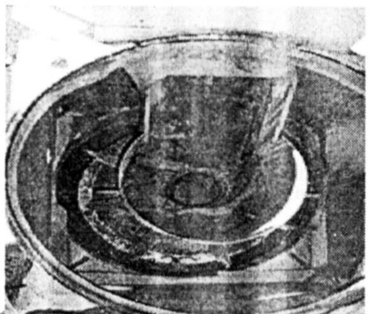
- Mason Sand
- Washed Mason Sand
- Premium White Bunker Sand
- Premium Buff Bunker Sand
- Concrete Sand
- Washed Concrete Sand
- Manufactured Sand for Asphalt Mixtures for road laying
- Washed Manufactured Sand for Special Type Plastering

A pile of manufactured sand produced from granite in US

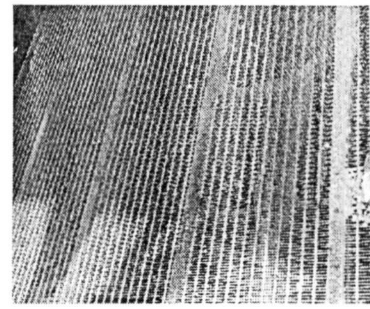


View of combined stone being fed into Vertical Shaft Impact Crusher

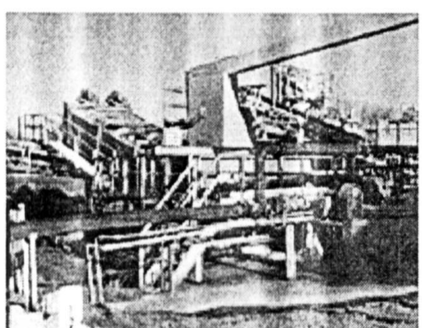
View inside the rotor of a Vertical Shaft Impact Crusher



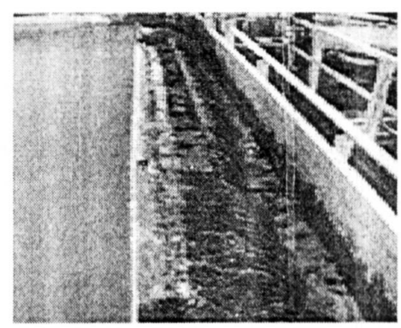
Close-up view of High Frequency Screen



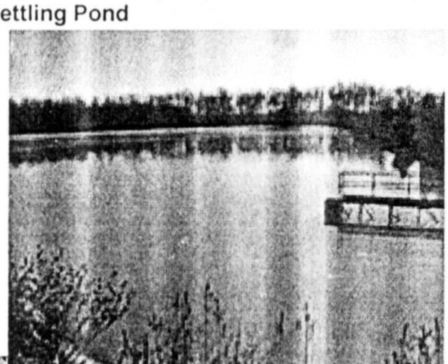
Final Processing Station .Sand Screw Classifier



Float Out Process



Fine particles are pumped to a settlement pond a Settling Pond



Manufactured Sand stockpile

Applications of Manufactured Sand

- In Asphalt
- In Concrete

Sand as a aggregate in the concrete influences many concrete properties, Including;
Strength
Workability
Finishability
Durability
Water Requirements
Shrinkage or Expansion (Volume Change)

ASTM C 33 Gradation Table for Fine Aggregate.

Sieve	Percent Passing
3/8 in	100%
No. 4	95-100%
No. 8	80-100%
No. 16	50-85%
No. 30	25-60%
*No. 50	5-30%
*No. 100	0-10%

*It is worth noting that the amounts of fine aggregate passing the No. 50 and No.100 sieves affect workability, the bleeding of the concrete, and surface texture.

User Benefits

- Pumping of concrete
- Segregation
- Finishing and Floating

Other Advantages

- Storage of Waste
- Reduced Waste
- Depletion of Natural Sand Supply

Rivers are exhausted of sand

THE SOURCE

The vital characteristics of produced sand are to be properly looked after;

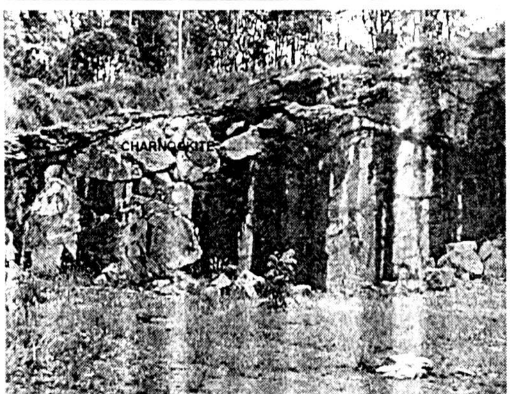
Specific Gravity
Organic Impurities
Abrasion Resistance
Soundness
Deleterious Substances
Particle Shape
Surface Texture
Bulk Density

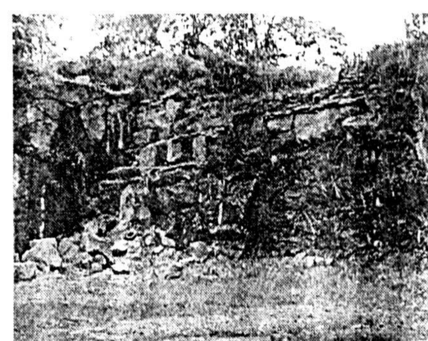
and a suitable parent material must be used for the manufacture of sand.

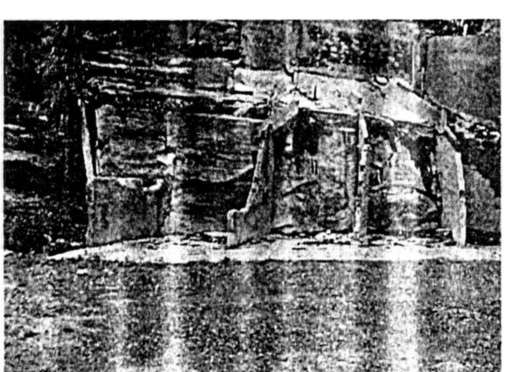
Common Sri Lankan rocks, minerals and their products of decomposition

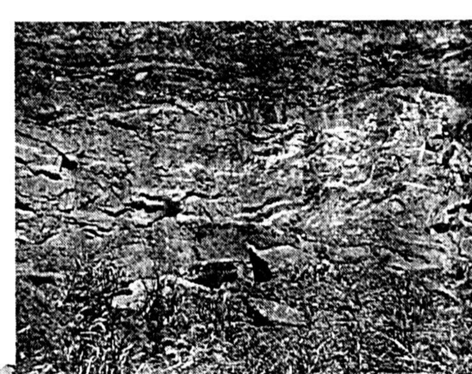
ROCK TYPE	MINERAL ASSEMBLAGE	PRODUCTS OF NATURAL DECOMPOSITION	NATURE OF THE PRODUCED SOIL
Charnockite	Quartz + Feldspar + Hypersthene + Garnet*	Quartz + Clay +iron Oxides	Clayey soil with little sand
Gneiss	Quartz +Feldspar +Biotite* Hornblende*+Garnet*	Quartz + Clay +iron Oxides	Clayey soil with little sand
Granulite	Quartz +Feldspar +Garnet*	Quartz + Clay +iron Oxides	Sandy soil with clay
Granite	Quartz +Feldspar + Hornblende*	Quartz + Clay +iron Oxides	Sandy soil with clay
Crystalline Limestone Marble	Calcite + Phlogophite* + Spinel*+ Garnet*	Calcite + Clay +iron Oxides	Clayey soil (calcareous)
[illegible]	Quartz + impurity minerals	Quartz	Sandy soil

* Minor and accessory minerals









these series was to show that the performance of Series 2 and 3 was similarly satisfactory, in contrast to the unsatisfactory performance of Series 1. Sea sand of typical grading was used in these tests. As this sand was stored outside the laboratory, it had been washed by rain over a period of time and was free of chlorides. All the sand samples were oven dried prior to being used in the concrete mix. The appropriate level of chlorides was introduced by using sea water (established as having 1.91% Cl^-) as part of the mixing water.

Three 100 mm cubes were cast for efflorescence testing. After demoulding on the following day, these were placed on supports in a basin with a shallow depth of water (so that they were clear of the water). The basin was covered with a polythene sheet secured along the top edge, so that the specimens were at 100% RH. After around 3 months, they were inspected for signs of efflorescence.

In addition, four specially fabricated 150 mm cube moulds were used to embed 2 nos. 10 mm mild steel bars each. The bars were machined down to 10 mm from a nominal 12 mm diameter. After being weighed, these bars were inserted at two corners of the cubes so that a cover of 20 mm was maintained to two of the cube faces. The moulds had a base plate with two holes into which the bars were inserted and also an arrangement to locate the bars at the top (see Figure 2).

Accelerated corrosion testing requires specimens having bars with small cover. However, a small mould cannot be used, as concrete with 20 mm aggregate cannot be vibrated into small moulds. Two alternatives are either to use mortar specimens or to saw specimens with small cover to bars from a larger cast specimen. Both these alternatives were deemed unsatisfactory, as they deviated from the materials in actual practice, where bars are embedded in concrete (as opposed to mortar) with covers to cast (as opposed to sawn) surfaces. The specimen developed here (see Figure 3) had small cover to the embedded bars on two faces and could be cast using concrete having normal (e.g. 20 mm) sized aggregate.

Four specimens (with a total of 8 embedded bars) were cast for each series. All of them were demoulded the day after casting. After one day of drying, the part of the bar protruding from the bottom of the specimen and part of the bar protruding from the top of the specimen (in contact with the concrete) were coated with epoxy. Two of the specimens were left to dry until an age of 14 days, after which they were placed in a carbonation chamber, where the conditions were 100% CO_2 and virtually 100% RH. The other two were cured in a water bath until an age of 14 days and then immersed to roughly half their height in a 5% NaCl solution.

The half-cell potential between the steel bar and the reference electrode was measured at the top, middle and bottom of each specimen (see Figure 4) at weekly intervals for the carbonation chamber specimens and twice weekly intervals for the NaCl bath specimens. An instrument employed had an Ag/AgCl probe, but the outputs were in the form of equivalent $Cu/CuSO_4$ potentials. The intention of these tests was to detect the time at which the onset of corrosion would be reflected in half-cell potential measurements. Although the exact boundary that demarcates corrosion cannot be drawn with great certainty, $Cu/CuSO_4$ potentials lower than around –350 mV indicate a high probability of corrosion.

4.5. Mortar and Plaster Mix Properties

The ICTAD Specifications (1980) were used to choose appropriate volume batched proportions for both mortars and plasters. These mortars and plasters were used by 3 separate masons with differing backgrounds to construct and plaster 900 mm high half brick wall panels outside the laboratory but under a wide roof eave; half of the plastered panels were coated with lime putty as well. Plastering was carried out a week after the panels were constructed. Sanstha Cement was used for both mortars and plasters, as it is very widely used among homebuilders; its comparatively slightly lower C_3S:C_2S ratio also makes it very suitable for mortars and plasters.

The ICTAD Specifications (1980) indicate that the volume batched cement: fine aggregate proportions for mortars could vary from 1:5 to 1:8. The richer mixes would be used in half brick walls. A proportion of 1:6 was chosen for this research, because it is widely used in practice. A volume batched cement: lime: fine aggregate proportion of 1: 1: 5 is specified for plasters. This however was modified to one of 1: 1: 6; once again because of widespread use. In general, it was sought to use somewhat leaner mixes, since such mixes would be used by a majority of the construction industry for reasons of economy; also leaner mixes would accentuate the effects of and distinctions between the fine aggregate types being tested.

The amount of water added to each mix (whether mortar or plaster) was controlled by the masons concerned, based on the workability desired by them. After the ingredients were mixed, two flow table tests were carried out as per BS 4551: 1980 and two cylindrical specimens of nominal dimensions 100 mm height x 95 mm diameter cast for subsequent 28 day wet cured strength testing after being capped with Plaster of Paris. The raw strength results were converted to equivalent wet cube strength values (Concrete 1976).

4.6. Practitioner Acceptability of Mortar and Plaster

The backgrounds of the three masons were as follows:

Mason 1 – 16 years' experience, mainly with private sector contractors
Mason 2 – 8 years' experience, with private sector contractors and in self-employment
Mason 3 – 30 years' experience, the majority in the State (i.e. university) sector

They were interviewed regarding the fresh state properties of the mortars and plasters they worked with. The relevant properties for the mortars were (i) adhesion, which would enable a wall to be raised with confidence and (ii) workability, by which was meant the ease of handling the mortar. The relevant properties for the plasters were (i) adhesion, with respect to sticking to the wall, (ii) finishing, meaning the ease of smoothening the surface and (iii) lime application, i.e. the ease thereof.

In order to assist the decision making process of the masons, a pair-wise comparison between each of the mortars (or plasters) was made for each property. If no difference was noted, both mortars (or plasters) received scores of zero; if there was a difference, the superior mortar (or plaster) received a score of +1 and the inferior one a score of –1. Such scores received for each mortar (or plaster) were summed for each property, thus enabling a property-wise comparison of the various fine aggregates used. In addition, the masons were also asked to make an overall ranking of the mortars (or plasters).

5. Results and Discussion

5.1. Fine Aggregate Grading

Figure 5 shows a comparison of the gradings of different types of fine aggregate. Quarry dust is the finest material and offshore sand (typical sample) the coarsest. Figure 6 shows the differences between the different samples (coarse, medium and fine) of offshore sand. The key information from Figures 5 and 6, and also from another set of sieve analyses of offshore sand (carried out at Sanken Lanka Ltd.), are presented in Table 3. Table 3 shows that the percentage passing the 0.60 mm sieve and the D_{50} values are very similar for different types of fine aggregate, despite significant differences in the percentage passing the 0.15 mm sieve. It also shows that differences between the typical, medium and coarse offshore sand samples are small, while the fine sample is considerably different, when considering data presented in Figures 5 and 6. However, the sieve analyses carried out at Sanken Lanka Ltd. show more differences between the coarse, medium and fine samples; here too however, the fine sample properties deviate considerably from the medium and coarse ones. It must also be appreciated that previous work has indicated that offshore sand gradings can vary from one location to another (Wijayananda 1994, Dias et al. 1999). Figure 7 in fact shows such variations in grading; they cause the offshore sand samples to be classified from C (coarse) to F (fine), as per BS 882: 1992.

5.2. Shell Content in Offshore Sand

Table 4 gives the results for the shell contents. The percentages are by weight of the total sample. The sample fraction above 5 mm is small, but most of it consists of shells; a shell content of around 2% can be assumed as being typical. If the sand is subjected to a sieving operation, this shell content can be used to produce lime (and could reduce the illegal exploitation of coral reefs that presently serves this purpose). The sample fraction below 5 mm is large; sand of finer grading has a higher shell content.

Table 4 also gives the BS 882: 1992 limits on shell content. There are no limits on the fraction below 5 mm. There is a limit of 20% for 5-10 mm aggregate and 8% for larger sized aggregates. The percentages in Table 4 are by weight of the fine aggregate sample. However, since the coarse aggregate content in a concrete mix will rarely be less than fine aggregate content, when offshore sand is mixed with coarse aggregate, the shell contents by weight of the coarse aggregate will be less than those by weight of the fine aggregate given in Table 4, and hence well below the acceptable limits. In any case, as pointed out before, shells are unlikely to impair either concrete workability or impermeability (Chapman & Roeder 1970).

5.3. Chloride Content in Offshore Sand

Table 5 presents four initial results taken from various offshore sand samples at various degrees of drainage. The similarities between these values and those from the sand column test (see below) should be noted.

Table 6 gives the results from the sand column (see Figure 1) test. The chloride content results are given in Figure 8 too; the "sea water" results correspond to 27 days' draining (see Table 6). Where the test method itself is concerned, it appears that generally high levels of moisture remain at the bottom of the column. This may be due to capillary action in the sand that retains moisture. In Set 1, i.e. after 5 days of draining the seawater, the Cl^- percentages are around 2% of the moisture content values (i.e. the known Cl^- concentration in sea water), indicating that the Cl^- testing process is validated. However, after 27 days of draining (Set 2), the Cl^-% at the top of the column is proportionately much higher than the moisture content. This may be due to local variations, and also to evaporation at the top of the column. Loss of sea water through evaporation (as opposed to drainage) will leave the chlorides in the sand. At any rate, after just draining alone, the Cl^- percentages at levels A, B and C are generally equal to or less than the allowable percentage worked out in Section 5.4 and Table 7.

After just 80 mm of simulated rain, the chloride percentages at all levels A to D are satisfactory, and after a total of 320 mm of rain they are very small indeed. It should be noted that when Set 3 was sampled (5 days after 80 mm of rain), 73% of the added water had drained out; when Set 4 was sampled (5 days after an additional 240 mm of rain), 96% of the total rain water added (corresponding to 320 mm of rain) had drained out.

It may be concluded that free drained sea sand will have chloride levels that are generally at the acceptable level, although some care should be taken if sea water is lost through evaporation. Even where moisture is trapped by capillary action, a small amount of rain water (e.g. 80 mm, which is around the lowest mean monthly rainfall in Colombo) will be sufficient to reduce chlorides to acceptable levels. It must be appreciated that these results are for a 2 m height of sand, and that some care, experience and perhaps mathematical modelling will be needed to extend the conclusions to greater heights of stockpile.

5.4. Acceptable Chloride Levels

Table 7 is an attempt to define an acceptable level of chloride ions in offshore sand for Portland cement (other than SRPC) reinforced concrete construction, taking as a starting point a value of 0.3% Cl^- by weight of sand, as argued in the literature review. From this must be deducted an amount corresponding to chlorides in cement, the maximum value of which can be taken as 0.05% (Gutt and Collins 1987). Assuming that the only other source of chlorides is the sand, the allowable chloride content in the sand is arrived at by dividing 0.25% by the sand/cement ratio. These ratios in Table 7 are conservative for 20 mm max. aggregate size mixes (see the mix design in Table 8), using as they do lower limits for cement contents and upper limits for sand contents. Volume batched mixes would have lower (and hence more favourable) sand/cement ratios.

Table 7 indicates that the critical case is grade 20 concrete; no structural concrete below this grade is allowed. A maximum chloride content of 0.075% by weight of sand could therefore be deemed acceptable for all reinforced concrete work using a 20 mm max. aggregate size and Portland cements other than SRPC. This assumes that there will be no chlorides added from the coarse aggregate or mixing water. The results in Tables 5 and 6 indicate that offshore sand saturated with sea water will clearly violate the above limit. Also, if offshore sand loses its sea water through evaporation, its chloride content is likely to be unacceptable. However, if it loses its sea water through drainage, then the Cl^- content would be reduced to almost the acceptable limit. Further flushing via rain or artificial washing would easily reduce the chloride level to acceptable values.

5.5. Concrete Mix Properties

Table 8 gives the concrete mix designs, together with slump and strength results for concretes made with offshore sand (medium grading); Table 9 gives similar data for concretes made with manufactured sand. In general the target strengths and slumps have been achieved other than for one or two minor deviations.

It should be noted that the grade 25 mix in Table 8 should have used 195 kg/m^3 of water rather than the 200 kg/m^3 actually employed. The figures in parentheses give the recommended (as opposed to actual) mix proportions. The recommended proportions will bring the slump down to the desired range of 120-180 mm, and will not affect strength (as the water/cement ratio is kept unchanged).

It should also be noted that manufactured sand fine aggregate mixes require around 20 kg/m^3 of extra water (over that required by the offshore sand mixes) in order to obtain the desired workability. This is because the manufactured sand is a crushed aggregate, whereas the offshore sand is not (Design 1988). This also means that the mixes in Table 9 will need around 10% higher cement contents (than those in Table 8) and will consequently be more expensive.

5.6. Efflorescence and Corrosion Tests

After three months of exposure to 100% RH, the Series 1 efflorescence specimens (corresponding to 0.3% Cl^- in the sand) showed droplets on their surfaces and a slightly whitish hue. This indicates that moisture from inside the specimens was being drawn to the surface with the chloride salt. No such phenomena were observed for the Series 2 specimens (corresponding to 0.075% Cl^- in the sand) or the chloride free Series 3 specimens.

The half-cell potential results from the accelerated corrosion tests were averaged to obtain average results at the level of (i) the single bar, (ii) the single cube and (iii) the given exposure condition. Variations between faces and across top, middle and bottom positions for a single bar (see Figure 4) were small.

Figure 9 shows the variation of half-cell potential with time for 3 typical bars (one from each series) in the 5% NaCl bath. The initial drop in potential for all bars is soon after curing to an age of 14 days. The subsequent potential of around –200 mV indicates a period where no corrosion takes place. The Series 1 bar shows a sudden drop to below –400 mV at around 25-30 days, indicating the onset of corrosion. The Series 3 bar in the chloride free control mix appears to have started corroding only after around 50-55 days, and the Series 2 bar after around 80-85 days. What is important is that the Series 2 bar (in the concrete with a permissible chloride level) is no worse (and in fact better) than one in the Series 3 control mix.

Figure 10 shows the overall average variation of half-cell potential with time for specimens in the carbonation chamber. The initial increase in potential is a result of air drying, though here too the Series 3 specimens do not increase in potential above around –400 mV. The subsequent behaviour is not as clear cut as in Figure 9, and here the behaviour of the Series 2 and 3 specimens tend to approach that of the Series 1 specimens. It is not clear whether corrosion is actually occurring in the carbonation chamber specimens, and longer observation is called for. What we can say once again is that the behaviour of the Series 2 specimens (where the concrete has a permissible chloride level) is no worse than the Series 3 control specimens.

Both the efflorescence and accelerated corrosion testing indicate that the Series 1 specimens are susceptible to efflorescence and early corrosion. On the other hand the Series 2 and 3 specimens appear to be similar, and not susceptible to efflorescence or early corrosion. This indicates that the allowable level of 0.075% Cl^- in the sand will result in concretes that are not significantly different to chloride free concretes, with respect to efflorescence and corrosion of embedded steel. It is advisable to carry out the accelerated corrosion testing for a longer duration, in order to obtain more data.

5.7. Mortar and Plaster Mix Properties

Table 10 gives the mix properties for the mortars and Table 11 for the plasters. The first thing to note is that there is remarkable similarity between the values (especially for flow, but even for strength) for the three masons, despite the differences in their backgrounds and experience. This indicates that masons' practices are reasonable consistent, and that our sample of three masons was sufficient to capture the features of that practice.

In Table 10 (for mortars) there is a clear difference, in both flow and strength values, between the uncrushed river and offshore sand on the one hand, and the crushed quarry dust and manufactured sand on the other. This difference is markedly less in Table 11 (for plasters) and is virtually non-existent in the strength results.

5.6. Practitioner Acceptability for Mortars and Plasters

Table 12 gives the results of the pair-wise comparisons and the overall ratings for mortars made by masons. Their overall ratings are also given, a score of 4 assigned to the first ranked mortar and one of 1 to the fourth ranked one. Table 13 does the same for the plasters.

In general, the uncrushed aggregate (river sand and offshore sand) have better workability and finishing properties, while the crushed aggregate (quarry dust and manufactured sand) have better adhesive properties. River sand has the greatest acceptability in the overall ratings for both mortar and plaster, followed by offshore sand and manufactured sand. Although quarry dust has the lowest average acceptability for both mortar and plaster, Mason 1 gave it top rating for plastering.

6. Conclusions

The following conclusions have been arrived at through the literature review and experimental programme.

6.1. Physical Properties

1. Although the grading of offshore sands can be variable, they are generally within the BS 882 limits, and can be used for concretes, mortars and plasters.
2. Both offshore sand and manufactured sand can be used in concrete mixes. However, the use of offshore sand is more advantageous, as the water content requirement is around 20 kg/m^3 lower; this results in cement contents that are around 30 to 40 kg/m^3 lower for concrete grades from 20 to 30.
3. The shell content of offshore sand is within BS 882 limits. The shells larger than 5 mm (which constitute around 2% of the entire sample) can be extracted for sale to lime kilns; this could reduce the harvesting of coral for lime production. The shells do not impair the workability, permeability or other engineering properties of the concrete.

4. Both offshore sand and manufactured sand are satisfactory for both mortars and plasters and reasonably acceptable to masons, although they may rank river sand as their first choice.

6.2. Influence of Chlorides

1. A conservative limit for allowable Cl^- ions in offshore sand for OPC based reinforced or metal-embedded concrete is 0.075% by weight of the sand. This is based on (i) an allowable Cl^- percentage of 0.3% by weight of cement (lower than the BS 5328: Part 1 limit of 0.4% to account for warmer Sri Lankan temperatures etc.); (ii) an allowance of 0.05% by weight of cement for chlorides in cement (which is the accepted upper limit); (iii) a sand: cement ratio of 3.3 (which will rarely be exceeded for reinforced concrete); and (iv) the availability of chloride free coarse aggregate.
2. Offshore sand saturated with sea water has a Cl^- content of around 0.3%, whereas if the seawater is gravity drained, it reduces to around the acceptable 0.075%. Some care has to be taken at the top of the stockpile where the Cl^-% may be higher due to excessive evaporation, and at the bottom of the stockpile, where sea water may be held by capillary action.
3. The action of even 80 mm of rain will reduce Cl^- contents to below acceptable levels, even at the top and bottom of a 2 m high stockpile. (The lowest mean monthly rainfall in Colombo is 71 mm in February).
4. The efflorescence and corrosion performance of grade 20 concrete (i.e. the most critical grade) with the allowable Cl^- content of 0.075% in the sand is satisfactory and similar to a chloride free control mix; on the other hand, a mix with 0.3% Cl^- in the sand shows clear evidence of efflorescence and early corrosion.

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Table 1 – Testing Strategy

Test category	Property tested	Offshore sand	Manufact-ured sand	Quarry dust	River sand
Aggregate Properties	grading	x	x	x	
	shell content	x			
	chloride content	x			
Mix Properties (Concrete)	strength	x	x		
	slump	x	x		
Mix Properties (Mortar and Plaster)	strength	x	x	x	x
	flow	x	x	x	x
	adhesion	x	x	x	x
Performance Properties (Concrete)	efflorescence	x			
	corrosion	x			
Performance Properties (Mortar and Plaster)	efflorescence (plaster only)	x			
	practitioner acceptability	x	x	x	x

Table 2 – Mean monthly rainfall (mm) for Colombo (Wickramauriya 2002)

Month	Rainfall (mm)
Jan	82
Feb	71
Mar	120
Apr	255
May	328
Jun	195
Jul	128
Aug	99
Sep	157
Oct	359
Nov	310
Dec	155
Total	*2259*

Table 3 – Grading characteristics of fine aggregate

Characteristic	Fine aggregate (Fig. 5)			Offshore sand types (Fig. 6)			Offshore sand types (SL)		
	Quarry dust	Manufac-tured	Offshore (typical)	Coarse	Medium	Fine	Coarse	Medium	Fine
< 0.60 mm (%)	49	50	44	42	49	85	32	45	67
< 0.15 mm (%)	18	11	2.6	2.5	2.7	12	1.3	1.6	3.3
D_{50} (mm)	0.60	0.60	0.63	0.66	0.60	0.21	0.72	0.63	0.45

Table 4 – Shell content (%) in offshore sand

Grading	Fraction	
	< 5mm	> 5 mm
Coarse	9.18	2.12
Medium	7.10	1.55
Fine	13.12	0.64
Typical	7.44	2.84
Limits (BS 882: 1992)	none	8 - 20

Table 5 – Chloride contents in offshore sand

Sample type (grading)	Drainage condition	Cl^- content (%)
typical	saturated	0.28
fine	saturated	0.27
medium	drained	0.082
typical	drained and rain exposed	0.021

Table 6 – Results of sand column test

Sampling Level (Fig. 1)	Set 1 – sea water; 5 days' drainage		Set 2 – sea water; 27 days' drainage		Set 3 – 80 mm rain water; 5 d. drainage		Set 4 – addl. 240 mm rain water; 5 d. drain	
	Moisture (%)	Cl^- (%)	Moisture (%)	Cl^- (%)	Moisture (%)	Cl^- (%)	Moisture (%)	Cl^- (%)
A	2.10	0.044	1.37	0.115	2.22	0.008	2.37	0.0003
B	3.94	0.088	2.38	0.054	3.44	0.007	3.58	0.0002
C	3.20	0.061	2.79	0.069	2.96	0.030	2.99	0.0016
D	15.69	0.387	12.39	0.314	8.88	0.075	9.97	0.0459

Table 7 – Chloride limits for sand to be used in concrete

grade	20	25	30
w/c	0.65	0.59	0.54
cement	275	300	325
sand	900	875	850
sand/cement	3.3	2.9	2.6
allowable Cl in sand (%)	**0.076**	**0.086**	**0.096**

Notes: 1. allowable Cl ion = 0.30-0.05 = 0.25% of cement
2. possible maximum for Cl ion in sand = **0.075 %**

Table 8 – Concrete mix design results (offshore sand as fine aggregate)

Grade	20	25	30
Target mean strength (N/mm^2)	30	35	40
Water/cement ratio	0.65	0.59	0.54
Cement content (kg/m^3)	300	339 (331)	361
Water content (kg/m^3)	195	200 (195)	195
Fine aggregate (kg/m^3)	877	837 (843)	814
Coarse aggregate (kg/m^3)	1031	1027 (1031)	1035
Pozzolith 300R (ml/m^3)	900	1017 (993)	1083
Measured slump (mm)	135	190	130
3 day strength (N/mm^2)	20	23	26
7 day strength (N/mm^2)	26	30	33
28 day strength (N/mm^2)	32	36	39

Table 9 – Concrete mix design results (manufactured sand as fine aggregate)

Grade	20	25	30
Target mean strength (N/mm^2)	30	35	40
Water/cement ratio	0.65	0.59	0.54
Cement content (kg/m^3)	331	364	398
Water content (kg/m^3)	215	215	215
Fine aggregate (kg/m^3)	818	785	753
Coarse aggregate (kg/m^3)	1041	1041	1039
Pozzolith 300R (ml/m^3)	993	1092	1194
Measured slump (mm)	70	165	135
3 day strength (N/mm^2)	18	21	25
7 day strength (N/mm^2)	23	26	32
28 day strength (N/mm^2)	29	32	40

Table 10 – Mix Properties for Mortars

Type of fine aggregate		River Sand	Offshore Sand	Quarry Dust	Manufactured Sand
Flow (mm)	Mason 1	126	128	172	173
	Mason 2	126	124	162	156
	Mason 3	119	120	153	156
	Average	*124*	*124*	*162*	*162*
28 day strength (N/mm^2)	Mason 1	3.0	4.3	5.3	4.4
	Mason 2	2.2	3.1	6.7	4.6
	Mason 3	3.2	3.3	4.2	4.7
	Average	*2.8*	*3.6*	*5.4*	*4.6*

Table 11 – Mix Properties for Plasters

Type of fine aggregate		River Sand	Offshore Sand	Quarry Dust	Manufactured Sand
Flow (mm)	Mason 1	143	169	187	182
	Mason 2	163	183	184	188
	Mason 3	167	171	196	189
	Average	*158*	*174*	*189*	*186*
28 day strength (N/mm^2)	Mason 1	2.7	3.2	3.1	2.8
	Mason 2	3.0	2.5	3.4	2.7
	Mason 3	-	2.8	2.8	2.5
	Average	*2.9*	*2.8*	*3.1*	*2.7*

Table 12 – Acceptability of Mortars by Masons

Type of fine aggregate		River Sand	Offshore Sand	Quarry Dust	Manufactured Sand
Adhesion	Mason 1	-1	-3	+2	+2
	Mason 2	+2	-1	-3	+2
	Mason 3	-3	-1	+3	+1
	Average	*-0.67*	*-1.67*	*+0.67*	*+1.67*
Workability	Mason 1	+2	+2	-3	-1
	Mason 2	+2	-1	-3	+2
	Mason 3	+3	+1	-3	-1
	Average	*+2.33*	*+0.67*	*-3*	*0*
Overall rating	Mason 1	4	2	1	3
	Mason 2	4	2	1	3
	Mason 3	4	3	1	2
	Average	*4.00*	*2.33*	*1.00*	*2.67*

Table 13 – Acceptability of Plasters by Masons

Type of fine aggregate		River Sand	Offshore Sand	Quarry Dust	Manufactured Sand
Adhesion	Mason 1	-1	-3	+3	+1
	Mason 2	+1	-1	+3	-3
	Mason 3	-3	-1	+1	+3
	Average	*-1.00*	*-1.67*	*+2.33*	*+0.33*
Finishing	Mason 1	-1	-3	+3	+1
	Mason 2	+3	+1	-3	-1
	Mason 3	+3	+1	-1	-3
	Average	*+1.67*	*-0.33*	*-0.33*	*-1.00*
Lime Application	Mason 1	-1	-3	+3	+1
	Mason 2	+3	+1	-3	-1
	Mason 3	+3	+1	-2	-2
	Average	*+1.67*	*-0.33*	*-0.67*	*-0.67*
Overall rating	Mason 1	2	1	4	3
	Mason 2	4	3	1	2
	Mason 3	4	3	1	2
	Average	*3.33*	*2.33*	*2.00*	*2.33*

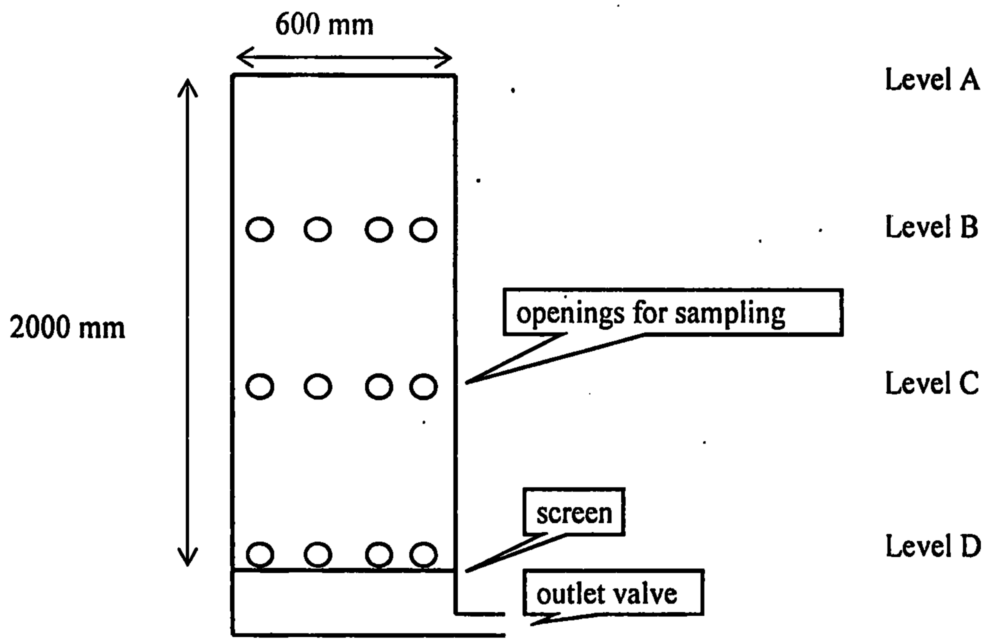

Figure 1 – Experimental setup for chloride profile testing in offshore sand

Figure 2 – Mould for accelerated corrosion test specimens

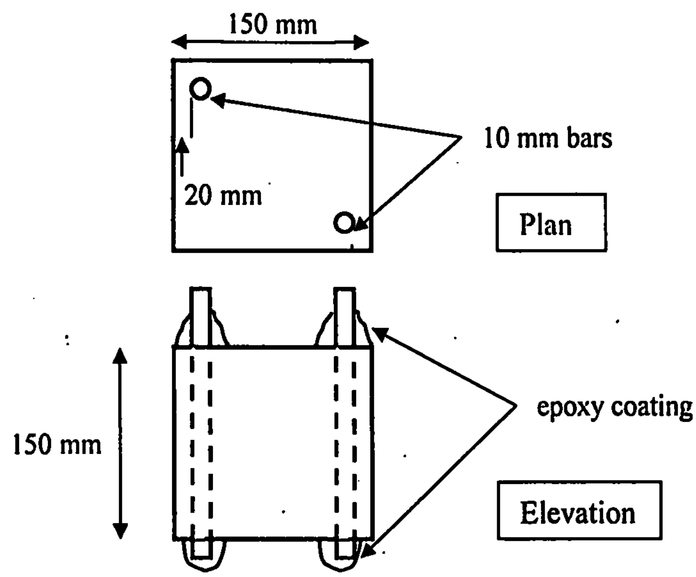

Figure 3 – Accelerated corrosion test specimens

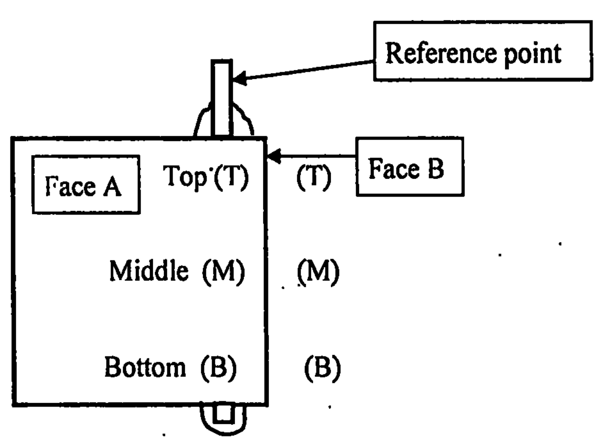

Figure 4 – Half-cell potential measurement locations

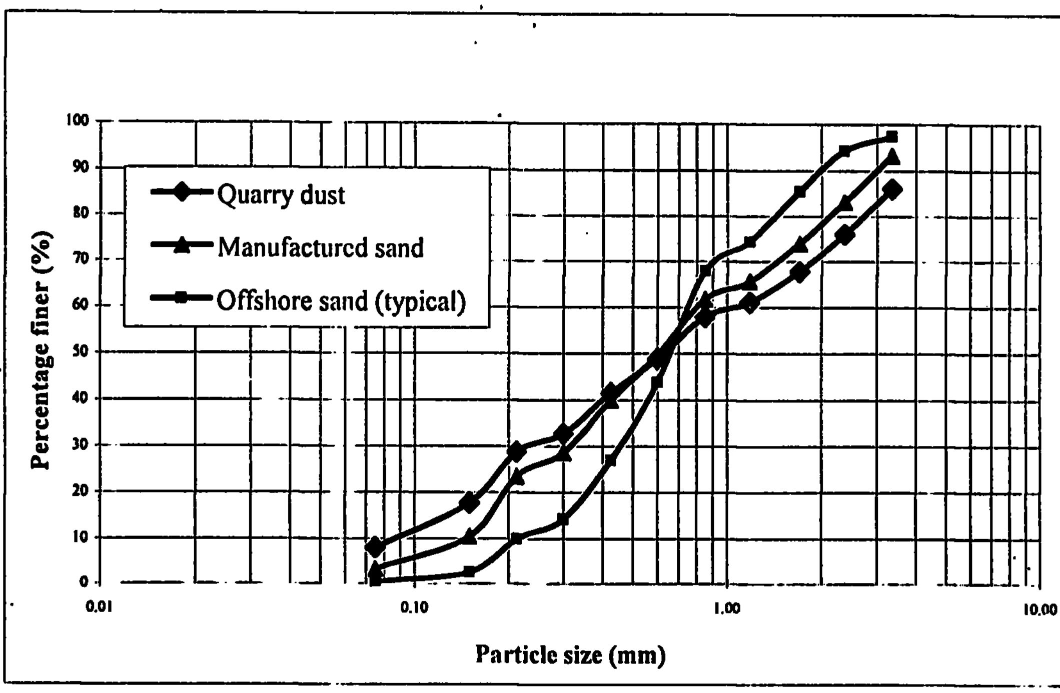

Figure 5 – Grading curves for different types of fine aggregate

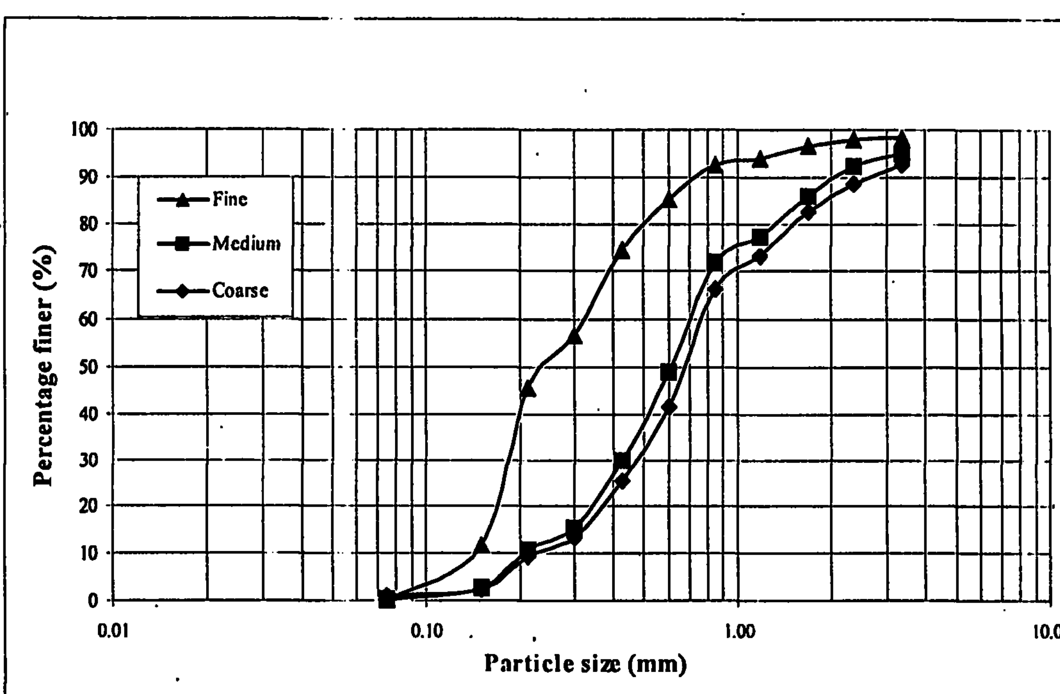

Figure 6 – Grading curves for different samples of offshore sand

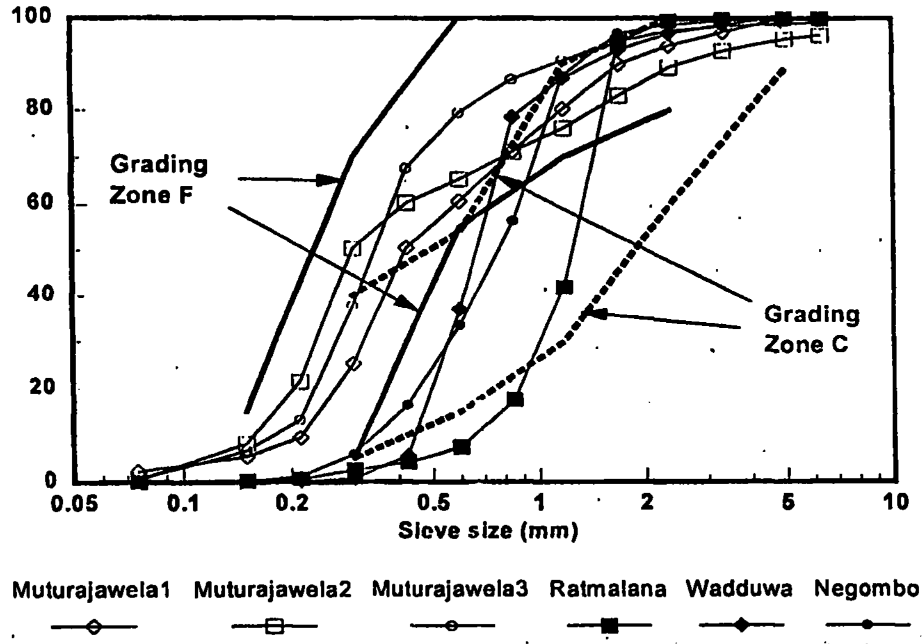

Figure 7 – Variations in gradings of offshore sand (from Dias et al. 1999)

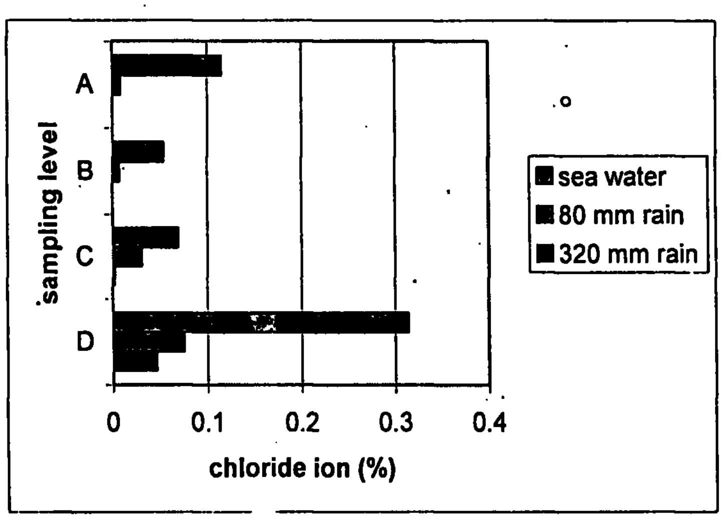

Figure 8 – Results from sand column test

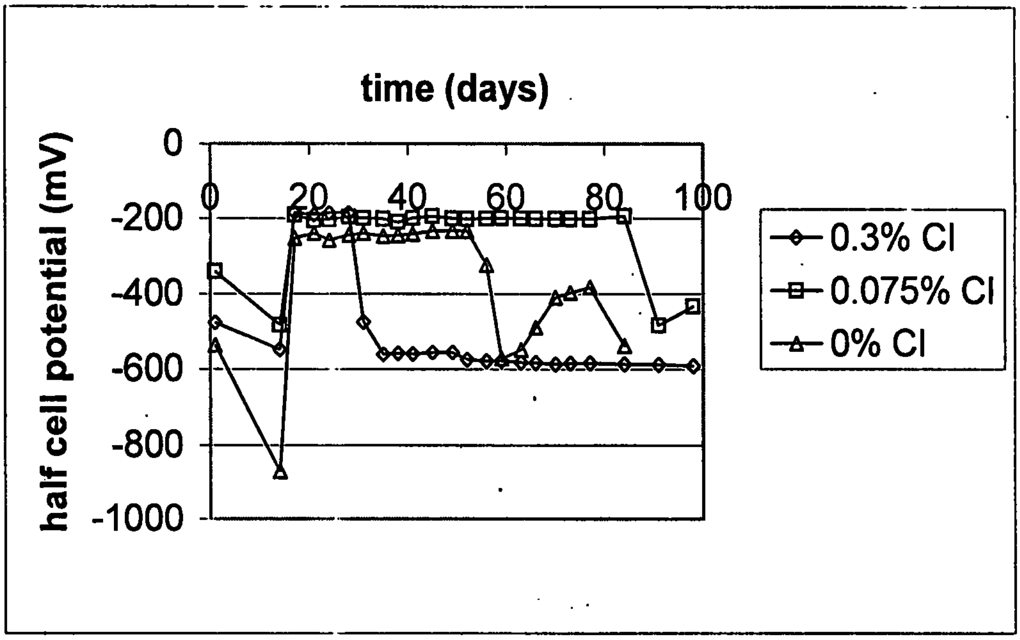

Figure 9 – Half-cell potential variation for a typical bar of a 5% NaCl bath specimens

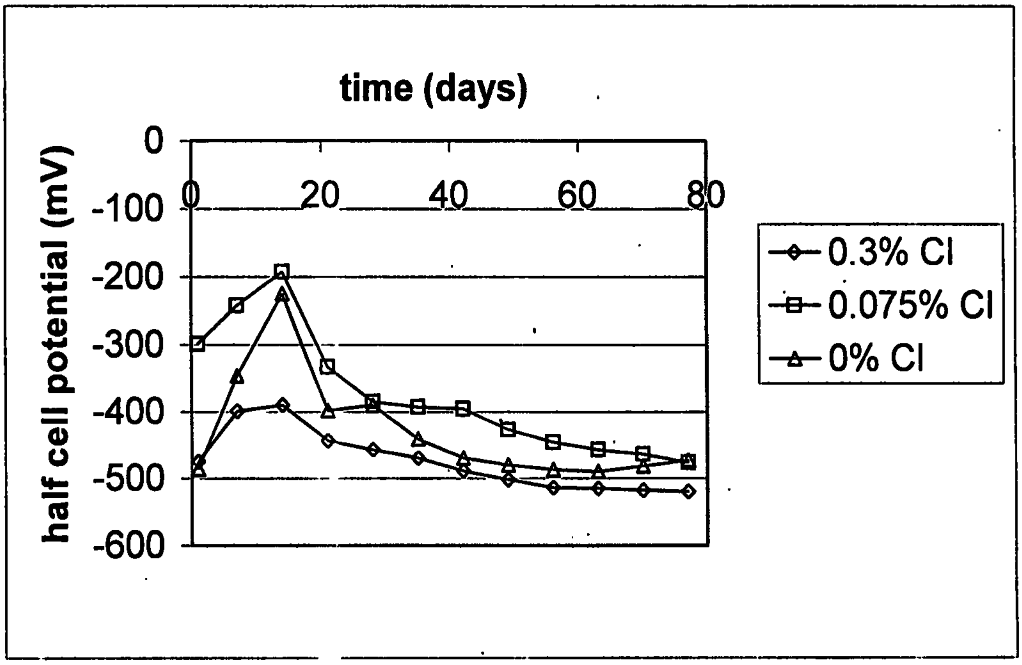

Figure 10 – Average half-cell potential variation (all bars) for 100% CO_2 specimens

Use of offshore sand in construction industry

Dr. SMA Nanayakkara,
Senior Lecturer,
University of Moratuwa

The mining of sand in the rivers for construction purposes has been identified for many years as a major environmental, social and economic problem for Sri Lanka. The main detrimental effects are coastal erosion and salinity intrusion into the rivers. The economic costs of these effects in terms of loss of land, loss of livelihood and degradation of water supplies are large. Because of these environmental problems, there is a necessity to restrict river sand mining specifically at harmful locations. In order to restrict river sand mining, it is necessary to introduce some alternatives for river sand to meet the demand. There are river sand alternatives such as offshore sand, dune sand, quarry dust and pit sand. Some of these such as dune sand and quarry dust are already in use but they do not satisfy existing depressed demand.

Of a total demand in the country for about 7.5 million cubic metres per year, about 3 million cubic metres or 40% is used in the Western Province, mainly in Colombo. If an alternative sand supply for Colombo can be provided, then the immediate pressure will be reduced in the other two provinces. It is clear that the only viable source of sand for Colombo is from offshore.

Existing Demand for sand

The present (2002) demand for sand for building construction within the country would appear to be in the order of 7 – 7.5 million cubic metres per year. The figure is based on reliable data on the amount of cement imported or manufactured in the country, and reasonable estimates of the amount of sand mixed with cement for concrete, plaster, mortar and other construction activities. The increase in the demand for sand for the construction industry can be estimated from the anticipated increase in the demand for cement. The average rate of increase in demand for cement for last six years is about 10%. If this average rate of increase is assumed to continue and is applied directly to the demand for sand, then the demand for sand over the next few years, in the areas with the biggest consumption, will be as shown in Table 3.

Table 3 Projected Sand Demand for the Construction Industry
(in million cubic metres per year)

Province	2002	2003	2004	2005	2006
Western	3.2	3.6	3.9	4.3	4.7
Southern	1.2	1.3	1.5	1.6	1.8
Central	1.0	1.1	1.2	1.3	1.4
Nth Western	0.8	0.9	1.0	1.1	1.2

Future demand for the Northern and Eastern Provinces is not possible to predict. However if hostilities in the country cease, it could be expected that there will be a very large increase in sand usage in those provinces.

Offshore sand sources

The only option that provides a large source of sand that is practically inexhaustible is offshore dredging of sea sand. It can be won with minimal adverse environmental effects and it can be placed in a stockpile on land at a reasonable cost. It would appear that there are sufficient deposits nearby to supply the main demand centre at Colombo for a long time.

Offshore sand is used in many countries for construction purposes. As an example, England currently mines about 25 million cubic metres per year of sand and gravel from its continental shelf.

Initially, even in other countries, some users were cautious about using offshore sand fearing harmful effects from the presence of shells and salt. In this they may have been influenced by the levels of such contaminants which may be found in unprocessed beach sand. It is now clearly established that these fears were groundless and that, provided offshore aggregates meet the appropriate specifications for aggregate such as BS 882, they are quite as effective for civil engineering and building construction as aggregates obtained from land.

Offshore sand availability

A number of studies connected with large projects have identified sources of sand offshore. Large sand deposits north of Colombo have been demarcated for the two projects, the Katunayake Expressway and the SAGT port terminal. An amount of 4.5 million cubic metres was dredged from a borrow area offshore in 20 – 25 metres of water for earthworks for the construction of the Colombo-Katunayake Expressway. Large deposits were also proven for earlier beach nourishment projects north of Negombo. Present indications are that there are very large resources of sand north of Colombo that could provide sand for the foreseeable future.

Because of the capital costs involved and other uncertainties, it is not viable for a Sri Lankan company to set up an operation to source and market offshore sand without the benefit of a pilot program. However if funds were available, preferably in some form of grant or concessional loan, to finance a pilot program, then it is likely that the secondary phase of commercialising the activity would be funded by industry.

Pilot project

Any move to change from river sand mining to offshore sand mining will have to be done on a large scale. This is because of the cost of mobilising a dredge and setting up the necessary storage and distribution system. It is not financially feasible for this to occur (with or without subsidy) until there is a substantial degree of acceptance within the construction community of the use of offshore sand.

It would be relatively easy to persuade some sectors of the industry to convert to offshore sand. Ready–mixed suppliers would take advantage of the consistency of supply and the uniformity of the material. Government sponsored projects could be enforced to use the sand by regulation. However the biggest users of sand are the home builders. They are more inclined to retain traditional methods than others. They and contractors are responsible for about 88% of the total use of sand. Contractors are normally bound by specifications supplied by engineers and architects. At present specifications produced by the Institute for Construction Training and Development (ICTAD) and which are used by the industry specifically require the use of river sand.

The only way that any meaningful change in the present practices of using river sand can be achieved is if these two groups, home builders and contractors, can be persuaded of the advantages of using offshore sand. This will not be easy and might take some time. However until it does happen, it is not feasible to set up commercial scale operations using offshore sand.

For this reason it is necessary to conduct a pilot project for the Western Province using offshore sand. This pilot project has to have the following components:

- A supply of offshore sand available in a stockpile;
- Accredited testing of the sand to ensure that it meets acceptable technical standards (mainly in the areas of grading and chloride content);
- Changes to the building specifications;
- Workshops to acquaint the industry with the present problems, the need for changes and the properties of offshore sand;
- Design mixes for concrete, mortar and plaster using offshore sand;
- Training courses and literature for home builders and contractors (i.e. masons) so that they can become familiar with the use of offshore sand;
- Subsidised supply of the offshore sand for the home builders and contractors to attract them from using traditional sources;
- Changes to Government regulations to force users on Government or BOI projects to use offshore sand.

Once there is an acceptance within the construction community of the use of offshore sand then there are regulatory mechanisms to force the use of offshore sand for certain projects. Once a commercial stockpile of offshore sand is available then other regulations can be used to prohibit and police the taking of sand from the rivers and the river banks with any mechanical equipment. This will limit the mass scale destruction that is occurring to the Maha Oya and the Deduru Oya rivers at present caused by mechanical equipment.

Engineering Properties of Alternatives for River Sand

Dr. S.M.A. Nanayakkara
Senior Lecturer
University of Moratuwa

Summary

Offshore sand, dune sand and land based sand have been identified as alternatives for river sand. Experimental investigations have been carried out to find their physical and chemical properties and properties of concrete made with these alternatives. It was found that all the offshore sand samples tested comply with the chloride limitation for normal reinforced concrete with OPC. However, it does not comply with that for prestressed concrete. In addition, it was found that chloride content of dune sand is extremely low and can be used for concrete without washing. The compressive strength results show that the concrete made with all three alternatives is as good as the concrete made with river sand.

1. Introduction

River sand is the most widely used fine aggregate in Sri Lanka. The average annual demand for sand is around 5 million cu.m and by the year 2000, the demand would be 9.6 million cu.m[1]. Due to large scale and uncontrolled river sand mining, there are environmental problems such as riverbank collapses, salt-water intrusion and coastal erosion. Because of these environmental problems, there is a necessity to reduce river sand mining especially at harmful locations. In order to restrict river sand mining, it is necessary to introduce some alternatives for river sand to meet the demand for sand. A few river sand alternatives such as offshore sand, dune sand, quarry dust and land based sand have been identified and some of these are already in use for various purposes. Out of the four identified alternatives, the quarry dust is widely used as a partial replacement of sands in concrete and other various applications. The properties of quarry dust and its performance are known to a greater extent. However, the other three alternatives are less known in Sri Lanka as alternatives for river sand specially for concrete. Therefore the experimental investigation is mainly focused on properties of offshore sand; dune sand and land based sand and their suitability for concrete.

2. Experimental Investigation

The physical properties of sand such as specific gravity, particle shape, particle size distribution, fine dust content were determined based on relevant British Standards[2]. The following tests were also carried out, based on relevant British Standards.

1. *Shell content*: BS 812:Part 106:1985 [3] describes the method for determining the shell content in coarse aggregate. This method was adopted for shells greater than 5 mm. Shell content in fine aggregate was determined by modifying the method given in the literature by Chapmen et al[4]. In this method, a representative oven dry sample of about 50 g is accurately weighed and standard hydrochloric acid solution is added to dissolve shells (calcium carbonate). Addition of hydrochloric acid is continued until there is no further reaction. The residue of the sand sample is carefully washed and the oven dried weight is

obtained. The percentage loss of weight of the sample indicates approximately the shell content in the sample.

2. *Salt contamination (water soluble chlorides)* : Chloride content was measured using a method for determination of chloride content in drinking water [5]. In the case of offshore samples, a wet sample was used after draining the excess water under gravity to obtain the highest possible chloride content. About 500 g of the sample was weighed and placed in a bottle; 500 ml of distilled water was added and the sample was agitated in a shaker for 24 hrs. The filtrate was tested to determine the chlorides in the sand sample.
3. *Compressive strength of concrete*: Since the main objective of the investigation is to find out the suitability of the selected alternatives for concrete, properties of concrete made with offshore sand, dune sand and land based sand were obtained. The standard mix proportion for grade 20 concrete given in ICTAD specifications[6] was used in this test. The slump and compressive strength at 7 days and 28 days were obtained.

3. Sand Samples

3.1 Offshore sand

As an island surrounded by the sea, Sri Lanka has access for considerable amounts of offshore sand deposits, existing mainly in the continental shelf area. In Sri Lanka, offshore sand has been used in beach nourishment and land filling work. Offshore sand samples were collected from locations in the western reaches of the continental shelf close to Ratmalana, Wadduwa and Negombo. These locations are about 1 km to 6 km from the shoreline and at a depth of about 14 m. Some samples were collected from Muthurajawela area since offshore sea sand was used to fill that area.

3.2 Dune sand

In Sri Lanka, dunes exist along the north-west coast between Chilaw and Kalpitiya, across Mannar island and the Pooneryn peninsula, along the north-east coast between Pulmoddai and Point Pedro and in the south-east coast from east of Ambalantota to Timitar[7]. Six dune sand samples were collected from Puttalam and Chilaw Districts.

3.3 Land based sand

Soil samples were collected from the Kosgama, Puwakpitiya, Bulathsinhala and Horana areas. Sand was extracted from these soil samples by washing manually. A steel wire mesh of 0.3 mm was used to extract sand from the soil in case of soil from Kosgama and Puwakpitiya and washed water was allowed to settle in order to obtain the clay. Sand extracted from these two soil samples were tested to obtain physical and chemical properties as well as the properties of concrete made with those sands. Sand from other soil samples was extracted using a 0.075 mm square mesh and only the composition of soil and particle size distribution of sand were obtained.

4. Test Results

4.1. Specific gravity and particle shape

Table 1 gives the specific gravity of the offshore sand, dune sand and land based sand samples tested. It can be seen that the specific gravity of dune sand is higher than that of the offshore sand and land based sand because dune sands are composed of quartz grain with a relatively high proportion of heavy minerals[7]. The water absorption is fairly low except for one land based sample. Although there is no clear-cut relation between the strength of concrete and the water absorption of aggregate used, the pores at the surface of the particle affect the bond between aggregate and the cement paste, and may thus exert some influence on the strength. And also it can be seen from the results given in Table 1 that the clay, silt and dust content(i.e. amount of materials passing through 75μm sieve) of offshore sand as well as dune sand is less than 3%, which is the limit given in BS 882 [8] for clay, silt and dust content in sand. Clay, silt and dust content of land based sand samples depends on the efficiency of washing. Since thorough washing was carried out, clay, silt and dust content in washed land based sand is very low.

4.2. Sieve Analysis

Figures 1, 2 and 3 show the grading curves for the offshore, dune and land based sand samples tested respectively. It can be seen that most of the samples fall into the overall limits specified in BS 882 [8]. It can be noted that particle size distribution of offshore sand samples vary from the coarser zone C to the finer zone F, whereas all dune sand samples fall into finer zone F. The particle size distribution of land based sand is in the coarse zone C and there is a deficiency in very fine particles in the samples from Puwakpitiya and Kosgama. This is because of the use of a coarse mesh (0.3 mm) in the separation of sand from these two soil samples. Since large quantities of sand were needed for other tests such as strength properties of concrete, a coarser mesh was used to separate sand. The use of a finer mesh like a 0.075 mm square mesh is not practical in large scale washing because it is a time consuming process to separate very fine particles from clay manually. And also it was found that most of the soil samples contain sand around 50% (by wt) (i.e. particles less than 5 mm) and also a fairly high percentage of clay (i.e. about 40% by wt. of soil). However, it is important to note that grading alone is not a governing factor to reject aggregates as blending and/or adjustment of the coarse to fine aggregate ratio are possible remedies.

4.3. Shell Content

The shells larger than 5 mm was found to be in the range of 0.6% to 5.3% for offshore sand samples. The shell content of the fraction less than 5 mm was found to be in the range of 6.5% to 39.0%. There were no shells in the dune sand. The BS 882[8] gives no limits for shells in sand, but limits shell content to 20% by weight in 10-5 mm aggregate and to 8% by weight in sizes above 10 mm. The presence of a large shell content has no adverse effect on strength but workability of concrete made with aggregates having large shell contents is slightly reduced[9].

4.4. Chloride Content

The chloride content of offshore sand and dune sand is given in Table 2. The samples taken from Muthurajawela show very low chloride content because that sand was exposed to rain for over a year and salt must have been washed away. Similarly dune sand also shows very low chloride content because these dune sands have got accumulated over very long periods and salt deposits on the sand must have been washed away by rainwater.

BS 8110 [10] and BS 882 [8] specify the limits for total chloride ion content in concrete and aggregate respectively as given in Table 3. The limits on the chloride content of aggregates given in BS 882 are for guidance only, since they assume that only aggregates contribute to the chloride content of the concrete. In practice, however, cement and admixtures contain small amounts of chloride and allowance may need to be made for this by a corresponding reduction in the permissible levels of chloride in aggregates. Table 4 shows the above limits (i.e. BS 8110 limits) converted to equivalent values expressed as a percentage of chloride ions by mass of fine aggregate, based on the prescribed mixes for ordinary structural concrete given in ICTAD specifications for Building works[6]. When calculating the maximum chloride content in Table 4 , it is assumed that chloride ions are contributed by fine aggregate and cement only. In addition, the chloride content of cement is assumed to be at the maximum of the typical range of 0.01~ 0.05% for OPC[11]. From Table 4, it can be noted that all the offshore sand samples tested comply with the requirement for normal reinforced concrete with OPC. However, it does not comply with that for prestressed concrete. In any case, it is better to wash offshore sand, but it is not necessary to do so in the case of dune sand.

4.5 Compressive Strength of Concrete

Table 5 shows the workability and the 7 day and 28 day compressive strength of a standard 1:2:4 concrete mix (quantities per cubic meter of concrete: cement – 320 kg, sand – 0.44 m^3 , coarse agg. – 0.88 m^3 , w/c – 0.55)[6] with river sand, offshore sand, dune sand and land based sand. It can be seen from the results that the compressive strength of concrete made with all the alternatives for river sand is as good as the strength of concrete made with river sand. Furthermore, concrete with dune sand gave the highest strength as well as workability. However, all mixes, including the mix with river sand, displayed generally low workability. The mixes with land based sand gave zero slump, which may be due to a deficiency in fine particles or due to the angularity of particles.

5. Conclusions

It was found that all offshore sand samples tested comply with chloride limitation for normal reinforced concrete with OPC. However, it does not comply with that for prestressed concrete. Grading of offshore sand varies from fine to coarse. Offshore sand can be used even without washing for production of concrete with OPC for normal RC structures. After washing, it can be used even for prestressed concrete because washing will lower the chloride content to a very low level. Since chloride content in dune sand is very low, it can be used for any type of concrete. The quality of the land-based sand depends on the type of soil and method of washing. Sand obtained from this method is suitable for works where coarse sand is required. The compressive strength results show that the concrete made with all three alternatives is as good as the strength of concrete made with river sand.

Acknowledgments

The author gratefully acknowledges the financial support given by the Central Environmental Authority of Sri Lanka. The author also wishes to thank Prof. Priyan Dias and Dr. Asoka Perera for their valuable assistance given for this study.

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Table 1 - Physical properties of river sand alternatives

Sample		Specific gravity (SSD)	Water absorption (%)	Clay, silt and dust content(%)	Particle shape
Offshore sand	Muturajawela	2.68	0.30	-	Rounded Irregular
	Ratmalana	2.75	0.20	0.42	
	Wadduwa	2.66	0.14	0.47	
	Negombo	2.71	0.10	0.39	
Dune Sand	Daluwa	2.78	0.23	0.3	Irregular
	Sinnapadu	2.89	0.29	0.64	
	Chilaw	2.78	0.32	0.9	
Land based sand	Kosgama	2.68	0.78	1.6	Angular
	Puwakpitiya	2.67	0.12	0.07	

Table 2 - Chloride content in offshore sand and dune sand

	Offshore sand			(Offshore sand)		Dune sand		
	Wadduwa	Ratmalana	Negombo	Mutu-1	Mutu-2	Daluwa	Sinnapadu	Chilaw
Chloride Content(%)	0.14	0.13	0.14	0.001	0.001	0.0004	0.0005	0.0009

Mutu – Muthurajawela

Table 3 - Limits for chloride ion in British Standards

Type of concrete	Mandatory limit for concrete to comply with BS8110:1985- Table 6.4 (wt % of cement)	Guidance limit for aggregate* in BS 882:1983 Table 8 Appendix C (wt % of aggregate)
Prestressed concrete	0.1	0.02
Concrete with SRPC	0.2	0.04
Concrete with OPC	0.4	0.06

* The combined aggregates, i.e., coarse and fine aggregate combined in the proportion to be used in concrete.

Table 4 - Equivalent values of chloride content limits

Grade	Mix proportion (kg/m³)			Maximum total chloride content in concrete expressed as a % of Cl^- by *mass of sand*		
	C	S	G	Prestressed concrete	Concrete with SRPC	Concrete with OPC
20	350	788	962	-	0.066	0.155
25	390	765	935	-	0.076	0.178
30	430	743	908	0.029	0.087	0.202

C – Cement, S – Sand, G – Coarse agg.

Table 5 - Properties of concrete made with various types of sand

Sample		Workability	Compressive strength(N/mm^2)	
		Slump(mm)	7 day	28 day
River sand		20	19.5	28.2
Offshore sand	Ratmalana	collapse	19.4	25.8
	Negombo	10	18.4	24.1
	Muturajawela	20	17.6	26.0
Dune sand		25	20.3	29.8
Land based sand	Puwakpitiya	0	16.9	27.4
	Kosgama	3	15.7	26.0

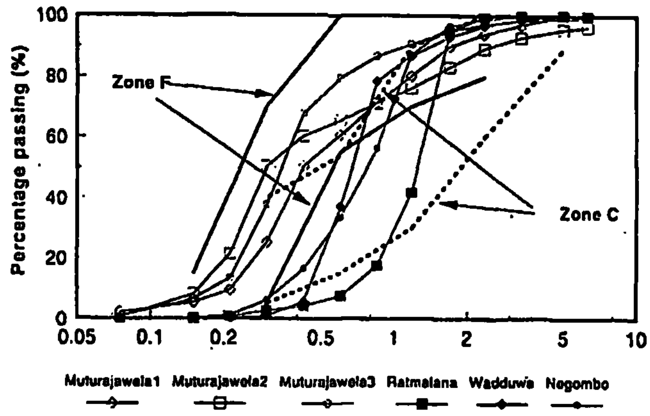

Fig.1 Particle size distribution of offshore sand

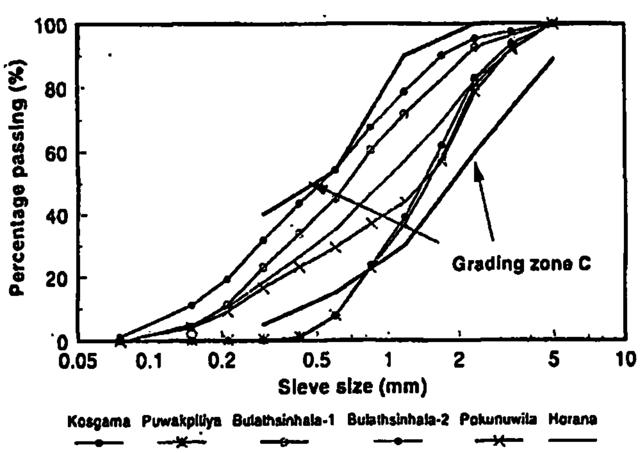

Fig.3 Particle size distribution of Land based sand

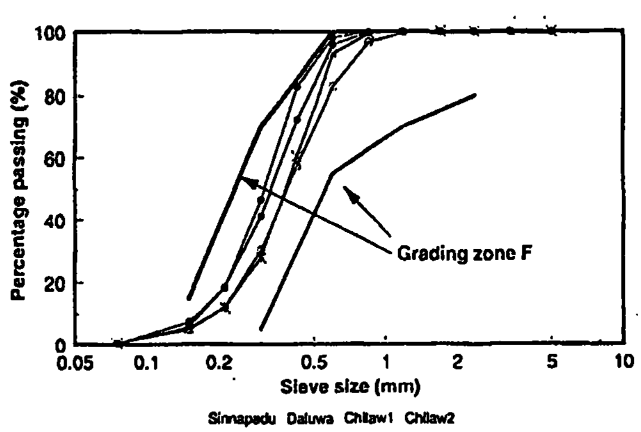

Fig.2 Particle size distribution of Dune sand

EVALUATION OF QUALITY RELATED FACTORS FOR BUILDING CONSTRUCTION

Abstract

Extraction of river sand beyond limits have caused many environmental problems. In order to search for alternative materials the National Building Research Organisation carried out research studies on dune sand, off-shore sand and crushed rock. These studies included

a. Sampling Surveys
b. Laboratory Studies and
c. Field Studies

Test results were compared with the relevant standards for the purpose of evaluation. A summary of this evaluation is given in the table annexed.

		Off-shore sand	Dune sand	Manufactured/ Crushed rock sand
1.	Particle size	Coarse to medium (but with exceptions)	Fine and contained within narrow grading envelope	Medium
2.	Particle shape	Similar to river sand	Similar to river sand	Elongated and irregular
3.	Content of fines (dust/ clay sized particles)	unless calcareous mud is present 0.2% to 1.5%, i.e. within permissible limit of 4%,	0.2% to 0.4% (well within permissible limit of 4%)	2% to 11% on material processed by washing/ sieving to remove excess fines (permissible limit : 16%)
4.	Composition (material other than sand)	May contain shells, shell fragments or some times calcareous mud (see Note)	Small percentage of heavy minerals	Same composition as in coarse aggregate
5.	Properties of cement/ sand or concrete mites – Workability & Strength gain	Similar to river sand	Good, especially in plaster/ mortar mixes May need more cement or mixing with other types of sand	Poor workability due to particle shape, but both strength and workability improved by blending with fine sand such as dune sand
6.	Deleterious material/ chemicals			
	- chlorides	0.01% to 0.2% (overall) but less than 0.05% in samples* in North-Western coastal shelf	Less than 0.02%	not applicable
	- sulphates	Less than 0.3% (within acceptable limits)	Insignificant	- do -
	- organic matter	insignificant	Very low (as confirmed by qualitative analysis)	- do -

Note : - Calcareous mud may be found in a narrow strip of sea shelf from Mt. Levenia to Panadura and from Beruwela to Matara
- Shell content in the Southern region is rather high – Some samples of off-shore sand (Hambantota and Nilaveli) contained over 90% shell and shell fragments
- If the size of shells are less than 5mm there is no limit specified for shell content in fine aggregate (i.e. sand used in concrete)
* Permissible limits of chlorides will depend on the type of concrete and the cement used, but the chloride level sand in NW would be acceptable for use in reinforced 0 concrete (not pre-stressed concrete) with ordinary portland cement

FULL PAPER

DUNE SAND, OFF-SHORE SAND & MANUFACTURED SAND

EVALUATION OF QUALITY RELATED FACTORS FOR BUILDING CONSTRUCTON

BASIS OF EVALUATION

Variety of samples were taken for

- Laboratory analysis and comparison of test results with standard specifications.
- Laboratory trials on identified concrete and mortar mixes for comparison with similar mixes using river sand.
- Field trials to obtain the views of engineers and masons.

SAMPLING

Dune Sand in NWP from Chilaw to Kalpitiya

Off-Shore Sand from Mirissa to Kirinda and Beruwela to Puttalam

grab samples taken to a layer thickness of ~ 1 m.

Manufactured Sand

(Crushed Rock)

P – Horana, Thalagala : Industry set up to manufacture sand

K – Athurugiriya } Required fine fraction separated during
W – Hokandara } metal quarrying

R – Hanwella } By-product of metal quarrying
D – Biyagama }

Off shore sand sampling

Details of Samples (see the map)

Sample No. and Location	Distance from shore Km	Depth from sea surface m	Description	Remarks
Samples from Kirinda to Mirissa				
3 Pitawatte	1.2	15	Coral/rock with little sand	Not useful
4 Hambantota	1.2	30	Sea shells with little sand	Not useful
5 Nilaweli bay	2.2	34	Corals with fine sand	Not useful
6 Dickwella bay	2.2	33	Sand with sea shells	Low strength
8 Mirissa	1.2	20	Sand with sea shells	Low strength

Sample No.	Distance from shore Km	Depth from sea surface m	Description	Remarks
Samples from Beruwela to Puttalam				
9 Beruwela	1.5	15	Silty sand	Cannot be used
10 Kalutara	3.6	19	Sand and shelly sand	Low strength
11 Panadura	3.3	20	Medium zone sand	Good for concrete
12 Mt. Lavinia	3.0	25	Silty sand	Cannot be used
13 Seeduwa	3.5	17	Medium zone sand	Good for concrete
14 Bolawatta	5.5	15	Coarse sand with sea shells	Good for concrete
15 Marawila	5.5	15	Medium zone sand	Good for concrete
16 Chilaw	5.5	15	Medium zone sand	Good for concrete
17 Mundal-Udappuwa	3.6	14	Sand with sea shells	Good for concrete
18 Mampuri	5.5	12	Sand with sea shells	Good for concrete
19 Puttalam	3.0	14	Coral shell debris with calcarious mud	Low strength

VISUAL OBSERVATIONS

- Dune sand : Fine quartz sand (consistent in particle size)
  Quartz : 80% - 94%, Calcite : 1% - 3%, Heavy Minerals : 3% - 15%,
- Off-shore Sand : Similar to river sand in particle size & shape.

Mineralogical Composition

Sample No.	% of Minerals		
	Quartz	Calcite	Heavy Minerals
S-8 Mirissa	32.05	67.47	0.48
S-6-1 – Dickwella	8.00	81.50	10.50
S – 4 - Hambantota	66.67	32.35	0.98

- Crushed Rock

Angular and irregular shape

Within medium zone classification

Manufactured sand has fine fraction removed (but still contains ~ 3% <0.075 mm)

Aim of manufacturing is to make the particles more rounded.

Physical Properties

Grading (Particle size Distribution)

Sand Type	Grading Pattern	Gr. Zone (BS 812)	Grading Envelope	Comment on Coarse fraction	Particle Shape
Dune sand	Well graded	Fine zone	Very narrow band	(90% < 0.9 mm)	More rounded than river sand
Off-shore sand	Well graded	Medium-coarse zone	Wide band but within limits	(90% <2.36 mm)	Similar to river sand
Manufactured sand	Well graded and fines reduced	Medium zone	-do-	10% - 20% >2.36 mm	Flaky and angular

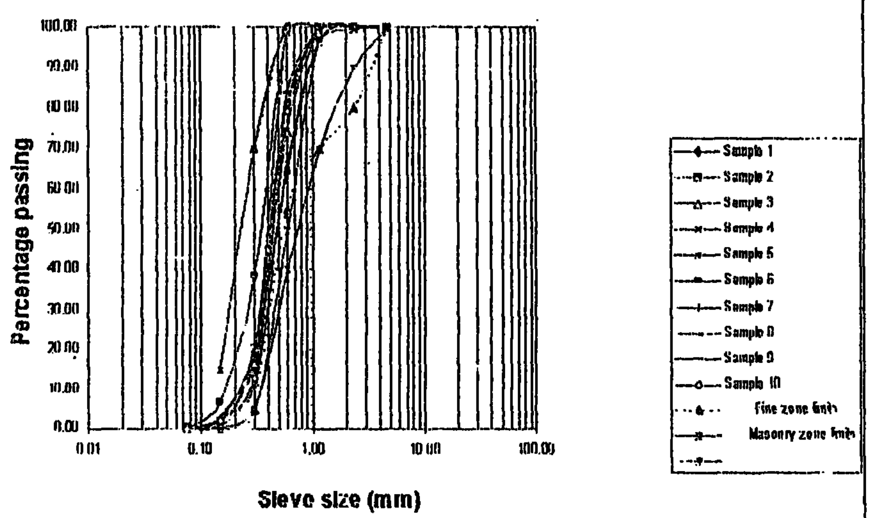

Fig. Grading Curves for Dune Sands

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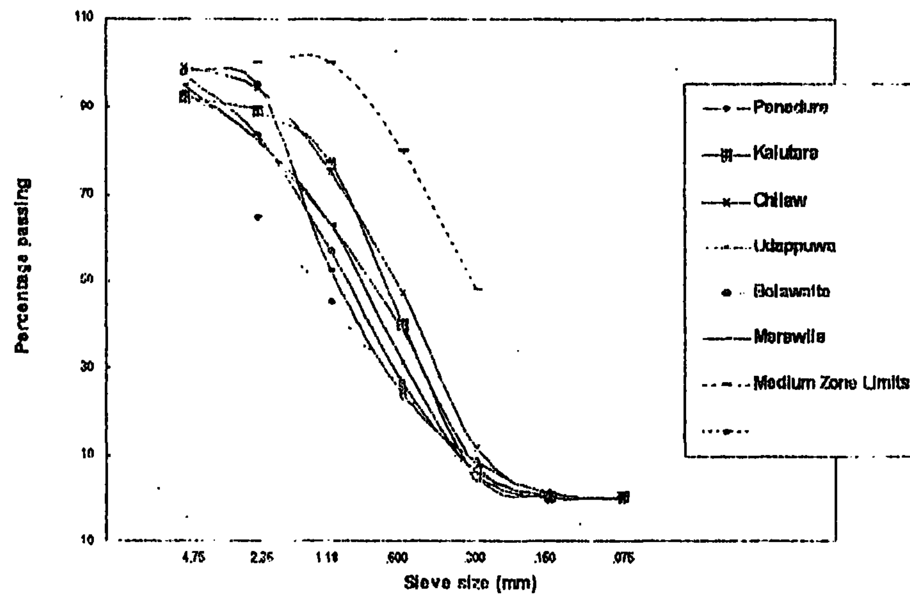


Fig. 2 - Grading Curves for Different Off-shore sands

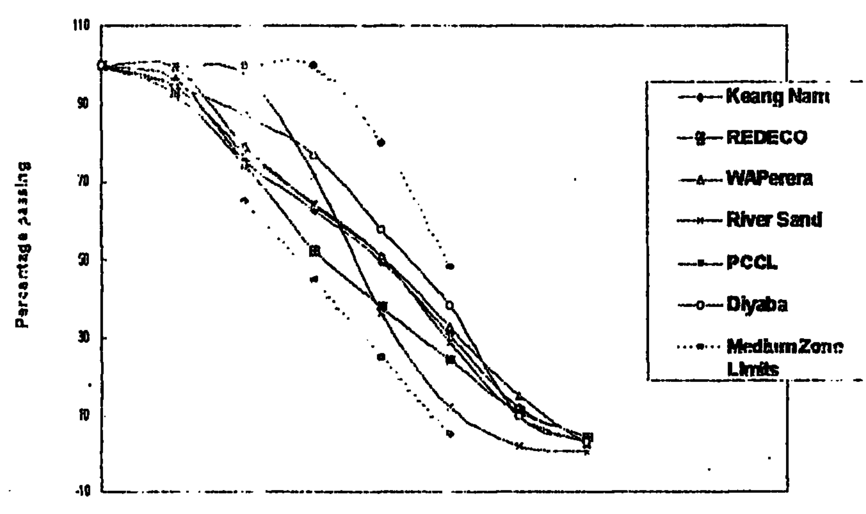


Fig. 1 - Grading Curves for Crushed rock samples

Specific gravity, Bulk Density and Water Absorption

Type of Sand	Specific Gravity (S S D)	Bulk Density (S S D)		Water Absorption	
		kg/m³	Rating	%	Rating
River sand	2.50-2.60	1450-1540	Low	0.20-0.26	Low
Crushed rock sand	2.65-2.72	1628-1720	High	0.55-0.69	Medium
Dune sand	2.72-2.80	1560-1720	High	0.50-0.67	Medium
Off-shore sand	2.55-2.70	1500-1650	Medium	0.20-0.84	Variable

Organic Impurities, Fines, Sulphates, Chlorides and Shell Content

Type of sand	Organic Matter %	Fine fraction (< 0.05 mm)	Sulphate as SO^3 w/w%	Chlorides as Cl^- w/w %	Shells %
1a. Crushed rock 1b. Manufactured sand	-	2-11 3	-	-	-
2. Dune sand	.0026-0.22	0.2-0.4	<0.001	0.002 - 0.022	-
3. Off-shore sand	-	0.02-1.5	< 0.3 %	0.086-0.204	0.16-13.3
Specified limits (BS 882:1992)		Upto 4% (but upto 16% for crushed rock)	Upto 3%	a) Reinforced concrete upto 0.05 % depending on cement type b) Prestressed concrete upto 0.01% c) Other concrete no limit.	a) For water retaining structures shells upto 30% (as per BS 5337) For b) others no limits specified

Fig. 7-day and 28-day Compressive Strength of Concrete Cubes Crushed rock sand, Dune sand and Off-shore sand

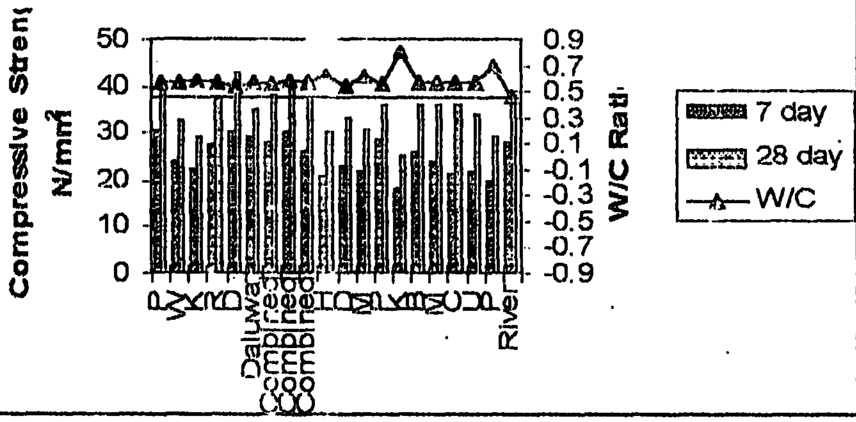
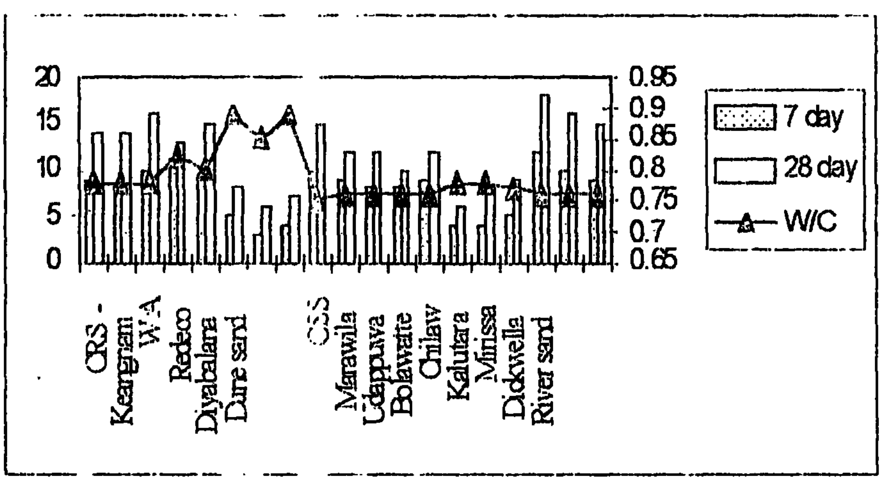


Fig. 4- 7day and 28-day Compressive Strength of Mortar Cubes Crushed rock sand, Dune sand, Off-shore sand and River sand (1:6 Mortar mix)



Field Trials

ICC Nivasipura Site

- Wall plaster using a) Dune sand

  b) Off-shore sand

  Area of 20 m^2 in 1:6 mix.

2. Concrete panel using the three alternative sand type

   Grade 25 concrete

   (designed for use with river sand)

   Mix proportions

   Cement 360 - kg/m^3, Fine Aggregate – 870 kg/m^3,

   Coarse Aggregate – 1030 kg/m^3, Water cement ratio – 0.55

3. Cement-sand blocks

   Using off-shore sand and crushed rock
   Mix proportions used 1:8 to 9 Cement : sand (Off-shore sand & Crushed rock mix

Observations and Results of ICC Field Trials

Trial	Observation	Results 7 d and 28 d strengths
Plastering		
Dune	Smooth surface, ideal for internal plaster good workability	(100 mm mortar cubes 1:6 cement:sand)
Offshore	Not very smooth surface. As good as river sand plaster	River sand 10 , 14 N/mm^2 Dune sand 5,8 N/mm^2 Offshore sand 12,14 N/mm^2
Concreting		
Dune	High workability, low slump value	100 mm concrete cubes Gr25
Offshore	Less workable, slump values same as river sand	River sand 20,35 N/mm^2 Dune sand 19,29 N/mm^2 Offshore sand 31, 36 N/mm^2
Cement blocks		
Offshore	Very good surface finish	2.3 N/mm^2

CONCLUSIONS

- Any alternative type of sand may not be suitable for all aplications.
- For a given application most suitable type must be selected and its properties must be taken into account.
- Use of nominal (volume) mixes are not a advisable (even with river sand). But if used after proper selection of materials and proper process control, desired results could still be achieved.

ECONOMICS OF RIVER SAND ALTERNATIVES

Asoka Perera
Senior lecturer
Department of Civil Engineering
University of Moratuwa

1.0 Alternatives and Business Scenarios

Construction Industry in Sri Lanka gets materials from both large scale manufacturers and small scale manufacturers. Cement, steel, sanitary items etc. are good examples for large scale production while common bricks, lime, sand are good example for small scale production and supply of building materials. At present sand is being mined at a level above the annual recharge that comes to rivers from their upstream catchments areas[1]. Therefore unless alternatives to river sand are not introduced to Sri Lanka's construction industry serious problems could arise within 10 to 15 years[2]. The possible alternatives[3] to river sand are:

1. Dune sand;
2. Offshore sand;
3. Land Based sand; and
4. Quarry dust.

Any alternative to sand to be used in the construction industry, firstly it should satisfy the engineering properties required and secondly the alternatives should be economical or at least same of prices of river sand. In this paper cost and prices of river sand alternatives are presented.

2.0 DUNE SAND

The total amount of sand that could be extracted from sand dunes in Puttalum district is around 9 million m3[3] and annual average demand of sand in Sri Lanka is around 3.5 million m3[1]. The initial investigation of this study observed indications that dune sand will be superior to river sand for applications such plastering, however may inferior to river sand in applications such as concreting. Therefore it seems not viable to mine dune sand to meet the total demand of river sand. Considering this dune sand option is presented as an option which could be used to partially replace the consumption of river sand. The initial investigation shows that an extraction level of 0.3 million m3 per year over a period of 30 years seems viable for the usage of dune sand in Puttlam district which could be transported to Colombo.

Considering the business approaches currently in Sri Lanka for the production building materials the following three approaches were identified to supply dune sand in Putlam district to Colombo.

1. Segregated business approach. In this case several medium scale business people's involvement to supply sand from sand dunes in Puttlam. In this approach a large scale capital will not be required, however there will be costs related to supervision by government agencies.

2. Large scale business approach. In this approach dunes could be sold to a single businessman or organisation with necessary rules as conditions of the sale. This organisation will be required to finance the machinery such as wheel loaders, big dump trucks and other resources.
3. Rail Transport System. In this approach it is proposed to use the rail network to transport sand from dunes. However it may be not immediately feasible considering the facilities available with Ceylon Government Railways. Therefore this option is not discussed in detail.

The details of above alternatives are presented.

2.1 Supply of Dune Sand by Medium scale business Personnel

The system proposed is as follows.

Table 1 Business Overview of Segregated business approach supply dune sand

Person	Work/ Responsibilities
1. Permit holder to extract sand from dunes and he should own machinery such as minimum of two wheel loaders, may be a few dump trucks and necessary manpower.	Should maintain an active supply point to customers who come to collect dune sand. The price must be an agreed price with the government and should obey the set rules by the government agency for sand mining.
2. Sand suppliers who own trucks. There should be some mechanism that construction industry could buy sand from some supplier who owns trucks.	To supply sand to the construction industry.

To acquire necessary equipment three options are possible. They are:
1. To hire equipment from reputed equipment hire company;
2. To acquire equipment of hire purchase agreement; and
3. To purchase equipment.

2.2 Dune sand from hired equipment

The fleet of equipment required for these operations is wheel loaders and large (25 Ton 10 Wheel trucks). The current market rates for the equipment are as follows.

Equipment	Hire rate
1. Front end wheel loaders of bucket capacity 1.2m3	Rs. 850.0 per day
2. 25 Ton trucks	Rs. 6000.0 per day

At least 20% discount could be obtained on long term hire of equipment. The annual cost of this process will be as given in Table 2

Total amount of sand transported per month = 25,000 m3
Cost of sand without overhead and profit = Rs. 320 per m3 or Rs 915 per cube
Cost of sand with 25% profit and overheads = Rs 432 per m3 or Rs. 1544 per cube

Table 2 Cost of Dune sand supplied from hired equipment

Description	Annual Cost Rs millions
1. Two wheel loaders at loading site near Puttlam	0.408
2. Internal roads and site office etc.	1.000
3. Staff cost at loading site near Puttlam Two wheel load drivers and two assistants - 0.336 Supervisor and office assistant - 0.168	0.504
4. Transport fleet of 40 25Ton trucks Hire rate for trucks - 57.600 Drivers and assistants - 6.720 Two mechanics for running repairs - 0.216 Diesel, oil, grease etc. - 13.068	77.604
5. Cost of working capital	0.625
6. Maintenance and staff of Colombo office - 0.960	0.960
7. Licence fee for sand extraction 25000 m3 per month for a period of one year - Cost per month less than 3.38 Acre of land to lower the depth by 2m Rs 50 per m3	15.000
Total	96.101

2.3 Dune sand from equipment acquired from hire purchase agreement

The equipment required for this operation are wheel loaders and large (25 Ton 10 Wheel trucks). The current market prices are as follows.

Equipment	Equipment Cost
1. Front end wheel loaders of bucket capacity 1.2m3	Rs. 3.5 Million
2. 25 Ton truck	Rs. 3.0 Million

The current hire purchase rate money borrowing for construction equipment is around Rs.5200 per Rs.100,000.

The cost of supply of sand will be as given in Table 3

Total amount of sand transported per month = 25,000 m3
Cost of sand without overhead and profit = Rs. 391 per m3 or Rs. 1118 per cube
Cost of sand with 25% profit and overheads = Rs 489 per m3 or Rs. 1396 per cube

Table 3 Cost of Dune sand supply from hired equipment

Description	Annual Cost Rs millions
1. Two wheel loaders at loading site near Puttlam	4.368
2. Internal roads and site office etc.	1.000
3. Staff at loading site near Puttlam Two wheel load drivers and two assistants - 0.336 Supervisor and office assistant - 0.168	0.504
4. Transport fleet of 40 25Ton trucks Hire rate for trucks - 74.880 Drivers and assistants - 6.720 Two mechanics for running repairs - 0.216 Diesel, oil, grease etc. - 13.068 Spare parts and other accessories - 12.000	106.884
5. Cost of working capital	0.625
6. Maintenance and staff of Colombo office - 0.960	0.960
7. Licence fee for sand extraction 25000 m3 per month for a period of one year - Cost per month less than 3.38 Acre of land to lower the depth by 2m Rs 50 per m3	15.000
8. Capital recovery after three years 63.50 after three years equal annual income	-11.982
Total	117.359

2.4 Dune sand from purchased equipment

The equipment required for this operations are wheel loaders and large (25 Ton 10 Wheel trucks). The current market rates are as follows.

Equipment	Equipment Cost
1. Front end wheel loaders of bucket capacity 1.2m3	Rs. 3.5 Million
2. 25 Ton truck	Rs. 3.0 Million

The current hire purchase rate money borrowing for construction equipment is around Rs.5200 per Rs.100,000.

The cost of supply of sand will be as given in Table 4

Total amount of sand transported per month = 25,000 m3
Cost of sand without overhead and profit = Rs. 243 per m3 or Rs. 694 per cube
Cost of sand with 25% profit and overheads = Rs 304 per m3 or Rs. 868 per cube

Table 4 Cost of Dune sand supply from hired equipment

Description	Annual Cost Rs millions
1. Two wheel loaders at loading site near Puttlam annual cost at 20% interest rate	1.923
2. Internal roads and site office etc.	1.000
3. Staff at loading site near Puttlam Two wheel load drivers and two assistants - 0.336 Supervisor and office assistant - 0.168	0.504
4. Transport fleet of 40 25Ton trucks Annual cost of trucks - 32.967 Drivers and assistants - 6.720 Two mechanics for running repairs - 0.216 Diesel, oil, grease etc. - 13.068 Spare parts and other accessories - 12.000	64.971
5. Cost of working capital	0.625
6. Maintenance and staff of Colombo office - 0.960	0.960
7. Licence fee for sand extraction 25000 m3 per month for a period of one year - Cost per month less than 3.38 Acre of land to lower the depth by 2m Rs 50 per m3	15.000
8. Capital recovery after three years 63.50 million : equal annual income	-11.982
Total	73.001

3.0 OFFSHORE SAND

Sand winning from offshore sources, although not common in Sri Lanka at present, had been in practice in many other countries, such as the United Kingdom, since a long time ago. Marine aggregates account for about 15 percent of aggregates used in Britain. Even in Sri Lanka offshore sand had been used previously in beach nourishment and land filling work. Offshore sand has been identified as one of the cheapest forms of fine aggregates. However, the presence of such impurities as salts and shells made see-dredged sand less popular in construction use. As see-dredged sand has been used as an economical option even as a filling material, it can also be an alternative for river sand, provided the necessary technical requirements are met[3].

The economics of offshore dredging depends on the scale of operation of the dredger. Large scale operation can reduce the unit cost of sand supplied at the stockpile. Dredgers are available with capacities ranging from several hundred cubic meters of sand a day to more than the annual requirement of sand in a few weeks. However, economical rates can only be achieved when the usage time of the machine is maximised. Therefore, round the clock operation of the dredger is usually preferred. In the financial analysis presented a trailing suction hopper dredger (TSHD) of relatively smaller capacity is assumed[3].

Well drained sea aggregates could be used in reinforced concrete without washing by fresh water. However if it is required to control the chlorides contents to very low levels offshore sand could be washed after pumping to the shore. This washing will lead to additional costs. Therefore the cost and prices of offshore sand without washing and with washing are presented separately.

The main capital cost of offshore sand mining is the cost of the dredger. Dredgers could be obtained from outright purchases, hire purchases or by hiring. Therefore cost of different options is presented separately. It is assumed that a trailing suction hopper dredger(TSHD) similar to "Diyakawa" owned by the Sri Lanka Ports Authority will be purchased and employed. It is further assumed that the TSHD will work 2 work shifts of 10 hours per day and 250 days per year. The productivity of the dredger will be as given below.

Cycle Time Calculation

Average sailing distance per cycle (2 to 6 miles travel)	= 9.0 nautical miles
Sailing speed	= 9.0 Knots
Average sailing time per cycle (up and down)	= 1.00hrs.
Average dredging time to fill the hopper	= 0.7 hrs.
Average coupling and decoupling time (with the pipeline	= 0.25 hrs.
Average discharging time	= 1.25 hrs.
Total cycle time	= 3.25 hrs.

Productivity calculation of the dredger

Capacity of the dredger	= 535 m3
Assuming 3 cycles per working shift and loading factor of 90%	
Daily production of the dredger	= 535x0.90x3x2 m3
	= 2,889 m3
Annual productivity of the dredger	= 2,889x250
	= 722,250 m3

3.1 Cost and Prices of Offshore Sand without washing : Purchase option

The different costs are given in Table 5.

3.2 Cost and Prices of Offshore Sand without washing : Subcontracting option

During both Negambo beach nourishment and Muthurajawela land filling, offshore dredging was carried out by expatriate contractors. The payments made in these contracts per meter of sand supplied at the beach are shown in the Table 6.

Table 5 Offshore sand from purchased plants and without washing

Description	Total cost Rs. millions	Annual cost Rs. Millions	Cost per m3
1. Investigation and Monitoring	29.79	4.53	6.28
2. Operating costs of the dredger Annual labour cost = 6.12 Annual fuel cost = 2.65 Annual maintenance cost = 12.00 Insurance premium = 3.00 Mooring charges/ other costs = 1.2	24.95	24.95	34.54
3. Capital cost of the dredger Purchase price = 500 Resale value after 30 years = 50 Discount rate = 15%	500 less 50 at year 30	76.04	105.27
4. Land cost discharging point land cost - 1.0 Acre = 12 50% appreciation at the end of 30 years 15% discount rate	12 and 18 at the end of 30 years	1.78	2.47
5. Capital cost at discharging point Office premises = 1.00 Plant, machinery and office equipment = 5.00 Working capital = 10.00	16.00	2.53	3.50
6. Operating costs at the discharging point Office staff, operators and labourers = 1.44 Equipment: maintenance = 0.50 Electricity, telephone water etc. = 0.10	2.04	2.40	2.82
TOTAL COST			154.89

Table 6 Rates quoted by Different Contractors for Off-shore Dredging

Dredging Contract and Year	Contractor	Rate Quoted per m3 (Rs.)
1. Negambo Beach nourishment (1989)	Danhoff (dredging had been subcontracted to DDD)	128.63
2. Muthurajawela land filling (1993)	Royal Boskalis	211.14

Assuming sea-dredged sand is supplied at the beach at a rate of Rs. 369.29 per m3 (assuming a 15% annual price escalation after 1993);

Buying rate of offshore sand at beach from subcontractor = Rs. 369.29 per m3
Unit cost of offshore sand bought, but unprocessed = Rs. 369.29 + 15.08
= Rs. 384.37 per m3

3.3 Offshore sand from purchase option with a washing plant

Once the sand is won from the sea, if the chloride content is higher than the chloride content limited by the design requirements, washing is necessary. Some researchers have investigated suitable processing techniques, and have suggested that the washing should incorporate some from of agitation like through an agitation screw or mixer and later good drainage. Therefore single screw washing plant (36"x25' , rate of processing 105 tph) is assumed for this process.

Required rate of sand processing

Daily production of sand = 2,889 m333 = 4,623 t

If the washing scheme also works 20 hours a day, required rate of processing = 232 tph

To facilitate an uninterrupted dredging operation, four washing plants of 105 tph capacity are assumed to be employed for the washing process. The system can run uninterrupted, even with two plants down simultaneously, by employing the remaining two machines 22 hours a day. With all four machines working the daily supply can be processed in 11 hours.

It is also assumed that these machines have lifetime of 15 years and no resale value. Therefore a complete replacement of washing plants and the water supply scheme is assumed at the year 15. Table 7 gives the details of the cost of a washing plant.

Table 7 Cost of a washing plant

Description	Total cost Rs. millions	Annual cost Rs. Millions	Cost per m3
1. Capital cost Initial cost of washing plants = 8.926 Installation, water supply, drains = 1.00 land for washing plant = 9.00 Life of plants = 15 years discount rate for capital = 15%	18.93 and 8.926 in year 15 less 13.5 in year 30	3.04	4.21
2. Operating cost Electricity = 2.36 water = 0.94 Maintenance and spare parts = 0.89 Labour cost = 0.86	5.06	5.06	7.01
Total			11.22

3.4 Market rates and offshore sand rates

It is important to compare offshore sand prices with river sand prices. the closest places to Colombo that offshore sand could be mined will be around Muthurajawela, Negambo or Wadduwa. The comparison is given in Table 8. It was assume that offshore sand will be sold with 35% profit and risk factor.

Table 8 Offshore sand Prices and River sand prices

Description	Offshore sand price Rs. per Cube	Price increase compare to rivers sand Rs. per cube Kelani (Rs. 633)	Maha Oya (Rs. 350)
1. Sand won unprocessed	575	-58	225
2. Sand Bought, unprocessed	1428	795	1078
3. Wand won, Processed	600	-33	250
4. Sand Bought, Processed	1454	821	1104

4.0 LAND BASE SAND

The rivers get sand from the natural process of washing soils in the land near to river banks. The initial investigations held at University of Moratuwa[4] has revealed that sand and clay could be extracted from the soils available in the banks of upstream of rivers such as Kelani, Maha Oya etc. The principle of extracting sand and clay from soil will be by washing using a mechanical washer. Suitable such lands are available in Homagama, Avissawella, Alavawa and other areas. This method has the following advantages.

1. Extraction of both sand and clay form same source.
2. Generation of employment in the use of clay in industries such as brick making, tile making etc. This may be a good solution to socio-economic problem created by the ban of sand mining from certain section of rivers.

Extraction of sand from soil involves the use of machinery such washers, bulldozers, wheel loaders, trucks and infrastructure such as water supply from tube wells or streams, internal roads settling tanks site offices etc. Therefore extraction needs to be done on medium or large scale basis.

4.1 Land base sand from medium scale operation

Medium scale sand extraction from soil can be defined as one with minimum use of machinery, use of land up to 150 acres and project duration of three years. Therefore the following are the requirements.

1. A total of 150 acres of land. This could be in one location or a collection of lands around 25 acres to 50 acres within 5km radius from a central washing location. It is assumed that soil can be cut on agreement to pay Rs.50 per cube as well as to develop internal roads for a development as per pre set blocking out arrangement. Rs. 50 per soil cube will give the owner of the land Rs. 225,000 per acre.
2. Washer at the site, one bulldozer, two front end loaders, two to five dump trucks (depending on the need which depends on the distances of borrow pits).
3. Duration of the first pilot project to be one year.

The following are the capital costs involved in cutting and transporting soil.

1. Earth moving equipment = Rs. 15 millions
   One bulldozer, 2 front end loaders and two dump trucks
2. Infrastructure development = Rs. 5 millions
   Site office, internal roads etc.

Total = Rs. 20 millions

Washing cost

Required rate of sand processing

Daily production of soil = 2125m3 = 3188 t

If the washing scheme works 10 hours a day, required rate of processing = 318 tph

To facilitate an uninterrupted soil washing operation, three washing plants of 105 tph capacity are assumed to be employed for the washing process. The system can run uninterrupted, even with one plant down, by employing the remaining two machines 15 hours a day. With all three machines working the daily supply can be processed in 10 hours.

It is also assumed that these machines have lifetime of 15 years and no resale value. Therefore a complete replacement of washing plants and the water supply scheme is assumed at the year 15. Table 9 gives the details of the cost of a washing plant. For this analysis it was assumed no resale value for the washing plant at the end one year too (since this could be first project).

Table 9 Cost of a washing plant

Description	Total cost Rs. millions	Annual cost Rs. Millions
1. Capital cost Initial cost of washing plants = 6.70 Installation, water supply, drains = 6.00 settling tanks, tube wells etc. Life of plants = 15 years	12.70	12.70
2. Operating cost Diesel and lubrication = 2.36 water = 0.94 Maintenance and spare parts = 0.89 Labour cost = 0.86	5.06	5.06
Total		17.75

Annual operating costs of cutting and transporting soil

1. Operator and labours costs = Rs. 1.068
   One operator and one assistant per machine, three labourers one supervisor and one operator for the machine
2. Fuel and lubrication = Rs. 3.8 millions
3. Maintenance of machinery = Rs. 1.5 millions
4. Insurance etc. = Rs. 0.4 million
5. Payments for soil = Rs. 11.25 millions
6. Contingencies = Rs. 0.57 million
7. Office and other overheads = Rs. 0.5
8. Working capital = Rs. 2.0

Total = Rs. 20.02 millions

Capital Recovery by selling of machines at the end of three years. Assume 50% resale value.

Description	Income after three year	Annual equivalent income at 15%
Earth moving equipment	7.5	7.5x.657x0.288
		1.42

Total cost per year = Rs. 17.75 + 20.02 - 1.42
= Rs. 36.35

Total amount of soil to be extracted from 50 acre land - one year duration
= 0.6376 million m3

1m3 of soil yields 0.295 m3 sand and 0.214 m3 of clay
Therefore 0.6376 million m3 of soil will yields 0.1879 m3 of sand and 0.136m3 of clay
Table 10 gives the cost and price of sand and clay.

Table 10 Costs and Prices of Sand and Clay

Description	Cost of sand per cube	Price of Sand with 35% Profits and overheads
1. Selling of sand only	194	261
2. If both sand and clay to be sold with equal price	112	152

5.0 QUARRY DUST AS A PARTIAL REPLACEMENT FOR SAND

The investigations has shown that quarry dust could be used as partial replacement for sand for some construction applications such as concreting, manufacture of pre-cast concrete elements, cement sand blocks etc. Today mainly because of the cement sand block industry quarry dust is more expensive than river sand. The current market prices of quarry dust are in the range of Rs.1600 per cube while river sand is around Rs. 1200 per cube.

In the investigations held on the feasibility of supper quarries also predicted that quarry dust produced by super quarries will more than 26% expensive than river sand. Therefore one could not expect a total replacement of river sand by quarry dust even for limited applications.

6.0 COMPARATIVE PRICES OF RIVER SAND ALTERNATIVES

Finally it is important to compare the prices river sand alternatives and Table 11and Table 12 give the prices. The current market rates from stock piles along river banks are as follows.

River	Sand Price Rs. per cube
1. Kelani river Abatale, Kaduwela area	630
2. Kalu ganga around Horana	600
3. Maha Oya around Sadalankawa	350
4. Sand price with transport to Colombo	1200

Table 11 Prices of River sand alternatives without transport

Alternative	Price of alternative Rs. per cube	Comparative river sand price Rs. per cube	Price increase of the alternative Rs.
1. Dune sand from Puttlam district	*868	*1200	-332
2. Offshore sand near Negambo	600	600	0.0
3. Sand from washing soil - Avissavella	261	600	-339
4. Quarry dust	*1600	*1200	400

* Price with transport

Table 12 Prices of River sand alternatives with transport

Alternative	Price of alternative Rs. per cube	Comparative river sand price Rs. per cube	Price increase of the alternative Rs.
1. Dune sand from Puttlam district	868	1200	-332
2. Offshore sand near Negambo	1100	1200	-100
3. Sand from washing soil - Avissavella	900	1200	-300
4. Quarry dust	1600	1200	400

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National Construction Association of Sri Lanka

SEMINAR ON ALTERNATIVES TO RIVER SAND
26September 2003

Introduction

Sand is the commonest naturally occurring raw material used in the Construction Industry in Sri Lanka. Most of our Building Structures are masonry or concrete structures as opposed to steel-framed structures common elsewhere. So whether it is cement mortar for bonding bricks, Plaster for surface finishing of walls, floor rendering or casting of concrete columns and floors, the vital fine aggregate used is sand.

Traditionally for many many years sand extracted from rivers and streams has been used for these purposes and nobody has voiced any objection or concern till recent years. With the growth of the population and the rapid need for infrastructure facilities and the expansion of the industry, the demand for sand has become unsustainable, the demand far exceeds the natural replenishment by sedimentation in our rivers. Ultimate result is over exploitation of the resources. As explained by the learned speakers in the previous sessions outcome is the detrimental impact on the environment. To cite a few of them once again

- River bank erosion leading to decline of land area
- Lowering of water table in wells affecting the community and agriculture.
- Vegetation loss and destruction of river morphology
- Coastal erosion
- Seepage of salt water in to rivers polluting community water supply schemes etc.
- Health issues related to spreading of diseases such as Malaria and other water borne diseases.
- Building damages and other infrastructure along the river banks due to water aggression.
- And many more.

Therefore it is understandable for the authorities to intervene **although late** to protect the environment and control the sand mining from our rivers.

Impact on the Construction Industry

We have no grouse with the authorities for formulation of legislation and imposing other restrictions for the protection of environment because Sri

Lanka cannot possibly allow the continuation of these environmental issues to affect our Eco systems, at the same time alternative sources for this vital construction raw material have to be found.

Already the construction industry has started feeling the pinch.

- Authorities have imposed restrictions or have banned extraction of sand from rivers, oyas and streams that have been the traditional sources of supply.
- Transportation of sand is banned or restricted
- Cost of river sand has rocketed up
- Scarcity of sand in the market
- Cost of construction has escalated and contractors are unable to maintain the prices committed to their clients during bidding.
- Delay in completion of projects

There are many stakeholders affected by this issue. They are the construction contractors, Ready mix concrete suppliers, cement block manufacturers, homebuilders who are the end users and State organisations executing projects /property developers, workers who earn their living through sand mining, Transporters etc.

Therefore alternatives have to be proposed taking care of interests of all the stakeholders mentioned above.

Usage Statistics

There are no records kept of the river sand mining operations and it is not feasible to determine directly the quantities of sand consumed in the construction industry. Many a surveys have been carried out by number of authorities to assess the quantity of sand extracted and its impact on the river system.

First survey commissioned by Coastal Conservation Dept (CCD) was carried out by the People's Bank in 1984 and updated in1991. Others have carried out subsequently many surveys, Delft Hydraulics did phase one of the National Sand Study (NSS) from 1991 to 1992 and they performed additional surveys and verified the sand extraction from the data for national cement consumption. Environment Action 1 Project has presented data extending up to 1997.

The trends established of usage of sand from the above studies

Sector	**Qty of sand Mtr. Cubes**
Building	2.8 Million
Highway	1.8 Million
Bridges	0.3
Water Supply	0.07
Irrigation	0.003
Dredging & Reclamation	0.001
Other	0.02

Current Demand

The recent demand for sand for construction within the island appears to be in the region of 7.5 Million Meter Cubes per year.
According to Byrne & Nanayakkara breakdown province wise is as follows.

Province	**Sand Vol. Million Mtr. Cubes**
Western	2.80
Central	0.85
Southern	1.00
Northern	0.15
Eastern	0.30
North Western	0.70
North Central	0.50
Uva	0.20
Sabaragamuwa	0.50
Total	**7.00**

It is estimated that annual increase in demand will be about 10% and with influx of donor funding above increase is expected to rise further.

The way out

Much has been said and discussed about alternatives to river sand during the last couple of years. The Academics and the professionals have discussed the alternatives available in detail in the earlier sessions. I do not wish to discuss the same details over again but would like to state that the National Construction association and its member constructors are caught between the devil and the deep blue sea. There are two schools of thought about the alternatives to river sand.

1. Moratuwa School of thought promoting Offshore Sand and

2. Peradeniya School of thought proposing Manufactured Sand as the best alternative.

Manufactured Sand talks of using crushed and mechanically ground quartzite a commonly occurring rock. Where as Offshore Sand considers dredging and pumping of sea sand to shore and processing it to meet permitted chloride content etc. As far as the construction industry is concerned pros and cons of the two alternatives are not our business. The learned members of the National Science Foundation, the Dons of the two schools of thoughts and the Authorities have to sort it out for us and provide the industry with a viable and a sustainable supply of fine aggregates at a manageable price.

It is well known that lot of spade work has been done about harvesting and processing of Offshore Sand under the Ministry of fisheries and Ocean Resources (MFOR) for setting up a Pilot Project. We have been involved with them in this regard and served on committees in the past with a view to some how or other resolve the problem that the industry was facing. Cabinet memorandum has been submitted by MFOR and approval obtained for setting up a company with 10% Govt. and 90% private sector investment. Although the proposal was to commence marketing operations in December 2002, sadly so far nothing has come about of this project and the industry goes on surviving with the help of hide and seek operations by the river sand exploiters.

In January 2003 Ministry of Irrigation and Water Management got awakened by the cries of environmentalists that Kelaniganga, Maoya and Deduruoya have become total environment disasters, gave instructions to take in to Police custody all the trucks and people involved in the sand transportation creating a big uproar. Subsequently the Minister summoned all and sundry involved , the environment protection people, sand mining and river management regulators, construction industry, truck owners etc. for a discussion in the Parliamentary Complex to decide on the policy and the strategy on the sand supply.

National construction Association at this stage expressed its willingness to set up an operation to market offshore sand provided concessions are arranged for obtaining mining licenses and land for stock piling, processing sand etc.

Subsequently NCASL formed a consortium of stake holders to embark on the project initial formalities were completed to establish a company. We wrote to all the relevant Government Ministries including the Prime Minister and Advisor to the Prime Minister outlining the proposal and seeking assistance specially for release of land by the Land Reclamation Board, BOI concessions and license for mining etc. The usual has happened, no satisfactory response has been received yet.

We pursued the matter further with the Minister of Housing and Plantation Infrastructure and met him on two occasions very recently to submit our proposals and reports on Offshore Sea Sand Project. He ofcourse summoned his officials for the discussion that was the end of our entrepreneurial attempt to solve the problem.
However we have now received a response from the Secretary to the Ministry dated 5 September 2003. On the advice of the Hon. Minister, he has instructed the Chairman Land Reclamation and Development Board to make necessary arrangements to make sea sand available to the construction industry by end December 2003. Initially borrowing one Million-meter cubes of sand from the RDA stockpile at Kerawalapitiya.
We are very happy about the news because our objective is to make sand available to any user freely and at a fair price.

We hope and pray that Land Reclamation Board will deliver the sand in the New Year. We are keeping our fingers crossed.

But still lot of things has to be done in the meantime. No body will accept sea sand in their projects unless it is approved by the client and the consultant. It has to be written in to the specifications in place of river sand. Not only ICTAD has to amend the Building Specifications, it has to create awareness among the end users, construction contractors, general public, homebuilders, masons etc. about the suitability of processed sea sand. Publication of Literature and Data sheets about the **New Fine Aggregate Sea Sand** has to be done immediately.

We have to wait 96 days more until 31 December 2003 to see where we have found the way out.

D.W.Balachandra
B Sc(Eng), C Eng, FICE, MIESL

Chief Executive Officer
National Construction Association of Sri Lanka
Savsiripaya
123, Wijerama Mawatha
Colombo 7.

Problems Faced by the Construction Industry

"We're simply out of natural sand here," said most mixtures control engineers. But what else can be done? An obvious answer is to use stone sand — manufactured sand —sea sand dunes- off shoe sea sand in concrete and cement products.

There are a number of benefits to using alternative sand. For example, when suppliers of crushed stone coarse aggregate also supply sand from the same mineral, it creates a homogenous concrete mixture. The appropriate use of manufactured sand can improve edge slump control during slip form paving. With proper water/cement ratios, concrete strengths may actually be higher with greater amounts of manufactured fines in the mix than with natural sand. And, of course, manufactured sand can fill the need in areas of the country where natural sand is becoming less available.

The testing and effects noted would include:

- Ease of handling raw materials
- Charging and mixing times in the plant
- Discharge and placement at the paving operation
- Finishability
- Set times versus ambient temperature
- Strength progressions
- Other physical properties of the hardened concrete
- Durability

But there are a number of unknowns yet to be addressed with the use of manufactured sand / sea sand in ordinary portland cement concrete.

Recommendation

- Focus! - immediate need of the country
- All alternative proposals to be start small and grow
- Prioritize a series of reasonable tasks considering burning issues of the construction Industry and the Environment
- Build on success, after success, after success!
- Do the most important thing first!

Recommendations

Local

Immediate implementation of monitoring mechanisms to ensure the environmental sustainability in river sand mining

Provincial

Implementation of alternative sand mining process

National

Establishment of National Policy for Industrial Sand Processing, utilization & conservation

Mr Viraj Dias

Response from the construction industry

Problems Faced by the Construction Industry

A A Virajh Dias
Laboratory & Site Investigation Unit
Central Engineering Consultancy Bureau

Sand Consumptions

- Dwellings
- High Rise Building
- Major Dams
- Ground Improvements
- Road & Infrastructure
- Other Structures...

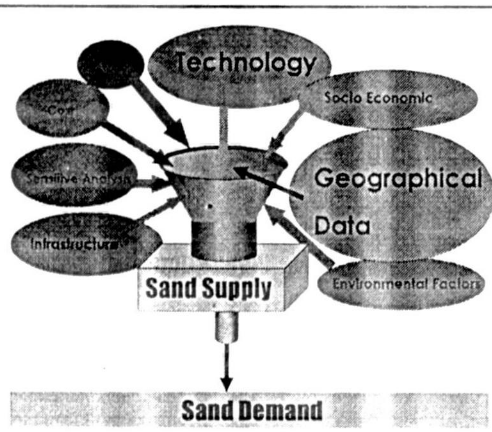
- Ready mix plant requirement is approximately 3000m³ /month

Sand consumptions

- Plastering and mortar
  - 12.5% - 20%: 1 Cement
  - 80% - 87.5%: 5 – 7 Sand
- Concrete
  - 14.3% - 18.1%: 1 Cement
  - 27.2% - 28.6%: 1.5 - 2 Sand
  - 54.5% - 57.1%: 3-4 Rock

Sand Consumptions

Single story buildings	~ 40%
Multi story	~ 35%
High rise buildings	~ 30%
Dams	~ 30%
Roads	~ 20 – 60%



Observations

- Aggregates occupies the largest volume in concrete and mortar, it affect both fresh and hardened concrete.
- Good aggregates (fine-sand and coarse-rock) supply is an essential constituent in concrete.
- Many years, extensive use of river sand in construction industry has had resulted in severe long term environmental consequences to the country
- Problem is acute in the North Western and Western Provinces (appr. 50% of the total sand requirement)

Observations

- There are no sufficient sand deposits in the rivers in the province to meet the demand.
- However,in Western and North Western Provinces, demand already exceed supply and consequently the unit price of sand is significantly increased within the last four years.
- There are reasonable alternatives available for the river sand. Those are manufactured sand, sea sand, off shoe sand, relic sand dunes and sand sediments trapped in estuaries.

Fine Aggregate

- Natural sand - obtained from the natural disintegration of rock, i.e. it shall be clean, sharp, river or pit sand free of earth, silt, clay loam carbon, alkali, mica, organic matter and other deleterious substances.
- Crushed stone sand – the use of this shall be permitted only for designed mixes. Crushed stone sand shall be manufactured from hard tough durable uncoated rock.
- Off shore sand which should comply with the requirements of BS 882 and its chloride content shall be such that the chloride ion contents with respect to combined aggregates.

Various properties of hardened concrete affected by aggregate are as follows

(a) Resistance to wetting and drying
(b) Resistance to heating and cooling
(c) Abrasion resistance
(d) Durability against reactive aggregates
(e) Fire resistance
(f) Acid resistance
(g) Strength
(h) Shrinkage
(i) Thermal Properties
(j) Unit Weight
(k) Modulus of elasticity
(l) Surface frictional properties

Advantages of river sand

(a)It contains no chloride or salt which may give rise to corrosion of reinforcement and efflorescence

(b)Being a natural deposit, grading of river sand is generally good

(c)It is more cubicle or rounded as opposed to angular and hence requires less water and cement to attain good workability.

Disadvantages are

(a)Now it is relatively expensive than sea sand

(b)Fluctuations in prices are greater in river sand depending on presence of rain and floods

(c)May contain organic impurities and silt

(d)May contain small gravel particles which are weak

(e)May not be abundantly available in the future as existing reserves are over exploited.

Sea / Manufactured Sand

Sea Sand

- Detailed characteristics of off- shore sand including mineralogy.
- Cleaning process including washing and removal of unwanted minerals.
- Energy requirement for pumping.
- Environmental impacts.

Manufactured Sand

- Shape, Gradation, Texture
- Detailed characteristics of mineralogy.
- Cleaning process including washing and removal of unwanted minerals.
- Energy requirement for processing
- Environmental impacts

Use of Off shore sand

- Producers must have separate stock pies of processed off-shore sand (i.e. sand ready to be used in concrete) to suit different types of concrete.
- Producers of off-shore sand to be used in construction to achieve product standard from SLSI to suit BS 8110 for each and every category above and to have ISO 9002 system standards.
- Producer must be responsible for the traceability of it's products being used.
- Sand extracted from the beach or from river mouth shall not be used as building sand.

CP 8110 states that

(a) Shells, flat or hollow, are comparatively unimportant in fine aggregate

(a) Total chloride content expressed as chloride ion per weight of cement shall not exceed 0.06% for prestressed concrete, or for reinforced concrete 0.35% for 95% of test results with no result greater than 0.50%. (% chloride ion x 1.648 - % equivalent NaC1)

IS 456 states that

(i) The level of chloride and sulphate in concrete coming from the concrete materials such as cement, aggregate, water and admixtures as well as by diffusion from the environmental shall be limited

(ii) Generally, total amount of chloride (as C1) and the total amount of soluble sulphates (as SO_3) in the concrete at the time of placing should be limited to 0.15% by mass of cement and 45 by mass of cement respectively

BS 5337 prohibits the use of marine aggregate in prestressed concrete but allows it for reinforced concrete provided

(i) Sodium chloride content of fine and coarse aggregate should not exceed 0.10% and 0.03% by mass of dry aggregate

(ii) If either aggregate exceeds the above limit total sodium not be greater than 0.32% by mass of the cement in the mix

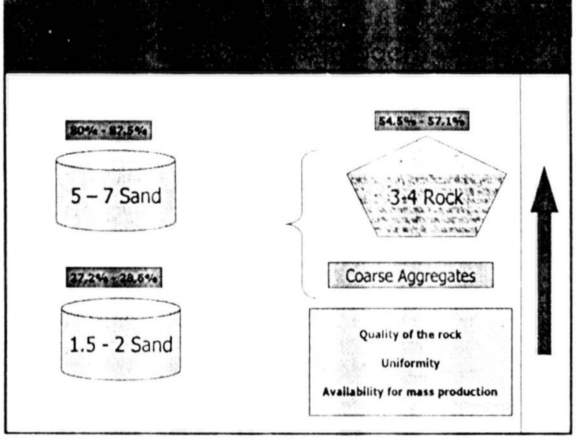
(iii) Shell content of fine aggregate should not exceed 30% by weight of dry aggregate

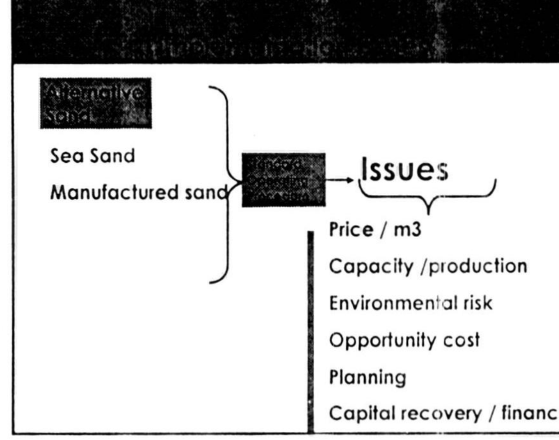
(iv) Water absorption of aggregate should not exceed 3%

Conclusions....

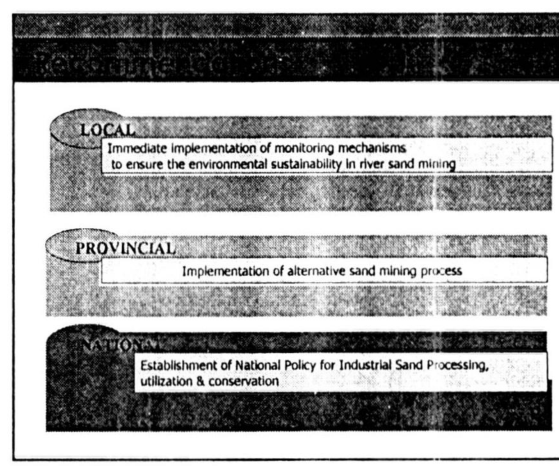
- To set up the necessary administrative and monitoring mechanisms to ensure the environmental sustainability in river sand mining.
- To provide necessary regulatory mechanisms and quality control measures
- Expedite the implementation of alternative process of sand production before meet an alarming event.

- **Geography, land use**
- **Accessibility**
- **Response assets**
- **Environmentally sensitive areas**
- **Socio-economic data**
- **Infrastructure**
- **Production Cost**
- **Variations**
- **Final cost**
- **Research**





- Focus! - Immediate need of the country
- All alternative proposals to be start small and grow
- Prioritize a series of reasonable tasks considering burning issues of the construction industry and the Environment
- Build on success, after success, after success!
- Do the most important thing first!



Thanks

Mr Anil Pieris

River Sand mining

Why Sand Mining become an issue ..?

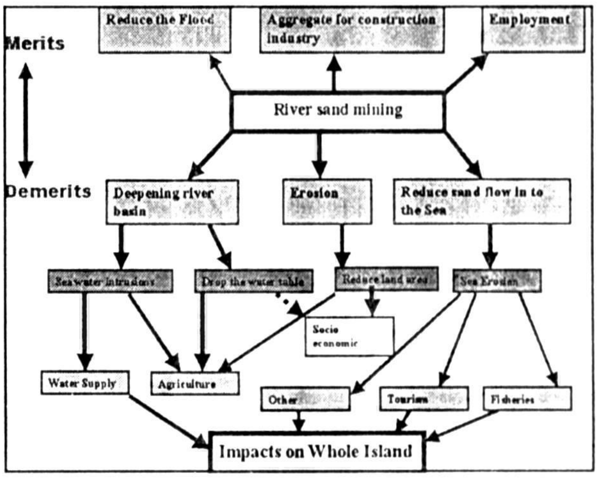
- Sand is non renewable resource.
- Annual Sand requirement of Sri Lanka is nearly 8,000,000 cubic meters.
- Sand demand increase by 10% each year.
- Still River Sand contribute 90% of total sand requirement.

Anil Peiris (Deputy Director Mines, Geological Survey & mines Bureau)

Environmental Impacts of River Sand Mining

- Erosion of river banks.
- Deepening the river basin.
- Drop the water table.
- Sea water coming into the land through the river flow.
- Increase the sea erosion
- Impacts to Fauna and Flora around the river bank.
- Damage to the permanent structures around river flow (Bridges, Roads, buildings Etc).
- Damage to natural drainage system.
- Pollute the river.

Anil Peiris (Deputy Director Mines, Geological Survey & mines Bureau)



Alternatives for River Sand

- Offshore sand.
- Dune sand
- Quarry dust

Anil Peiris (Deputy Director Mines, Geological Survey & mines Bureau)

Offshore Sand

- High capital investment.
- Salinity should be removed.
- Close monitoring required.
- Equipments and technology.

Anil Peiris (Deputy Director Mines, Geological Survey & mines Bureau)

Dune sand

- Practical size (very fine)
- Should mix with River sand or Offshore sand.
- High cement consumption.
- Much suitable for plastering.

Anil Peiris (Deputy Director Mines, Geological Survey & mines Bureau)

Quarry dust

- Particle size distribution (higher percentage of fine practical).
- Practical shape (round shaped particle reduce bonding ability).
- High cement consumption.

Anil Peiris (Deputy Director Mines, Geological Survey & mines Bureau)