Comparative Studies on Compressive Strength of Concrete Using Dredged Marine Sand

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Major Project

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(Computer Aided Structural Analysis and Design)

By

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May 2014

Declaration

This is to certify that

i) The thesis comprises my original work towards the degree of Master of Technology in Civil Engineering (Computer Aided Structural Analysis and Design) at Nirma Univeraity and has not been submitted elsewhere for a degree.

ii) Due acknowledgement has been made in the text to all other material used.

Parmar Ravi A.

Certificate

This is to certify that the Major Project entitled **"Comparative Studies on Compressive Strength of Concrete Using Dredged Marine Sand"** submitted by **Parmar Ravi Amarsinhbhai (Roll No: 12MCLC34)** towards the partial fulfillment of the requirements for the degree of Master of Technology (CIVIL Engineering) in the field of Computer aided structural analysis and design of Nirma University is the record of work carried out by him under our supervision and guidance.The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of our knowledge have not been submitted to any other University or Institution for award of any degree or diploma.

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Abstract

The depletion of source of natural aggregate necessitates to discover its alternative. Sand is important constituent of concrete which is generally obtained from the quarries or alluvial river beds. More extraction of sand from the river bed has become harmful for environment due to depletion of sand layer. Therefore, it becomes necessary to find out the alternative which can serve as long term replacement of sand. To counteract this problem, research is going on investigating the suitability of dredged marine sand, off-shore sand and dune sand as replacement for river and. In this study, the efficacy of marine sand is investigated as a replacement for natural river sand.

To examine the performance of concrete with dredged marine sand in terms of compressive strength, concrete cubes are cast by varying grade of concrete (M25 and M40) and % content of river sand replaced by DMS (0% and 100%). Exposure condition is assumed as very severe similar to marine environment. Since study is carried out for pumpable concrete, 25% fly-ash is added as a mineral admixture in both the grades of concrete. Aim of this study is to scrutinize the effect of replacement of river sand with marine sand on compressive strength of concrete. For durability studies plain concrete cubes are placed in sulfate exposure and chloride exposure.

Similarly, RCC slab panels are cast by varying two parameters, compressive strength of concrete (M30 and M40) and % content of river sand replaced by DMS (0% and 100%). Cores are extracted from these panels. Water permeability test, water absorption test, carbonation test and Rapid Chloride Penetration Test (RCPT) are conducted on these cores.

The project mainly concentrates on the use of Dredged marine sand (DMS) as a fine aggregate during casting of concrete and evaluating the mechanical properties like compressive strength & Durability properties. Sulfate, Chloride exposure, Water

permeability and RCPT tests for plain concrete cubes are done in present investigation. Standard size concrete cubes are cast as per IS provisions. Change in the appearance and change in mass after exposures in all chemicals are observed and studied for durability properties. Also, the non-destructive testing is performed for the concrete specimens.

The results related to mechanical and durability properties for all concrete mixes have suggested adequate performance of concrete made with dredged marine sand as compared to the concrete with natural river sand. Mechanical properties of concrete made with dredged marine sand indicate higher results for concrete made with 100% dredged marine sand as compared to that of concrete made with 100% replacement of river sand.

Thus investigation suggests successful use of dredged marine sand in concrete as a fine aggregate in construction activities. Furthermore investigation is to be done related to the chloride resistance of concrete with dredged marine sand.

Acknowledgement

I cannot present this work without first expressing my appreciation and gratitude to **Dr. Urmil V. Dave**, for their valuable guidance and constant encouragement at every stage of progress of the major project work.

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Nomenclature

RS/NRS .... River Sand / Natural River Sand

DMS .... Dredged Marine Sand

OPC .... Ordinary Portland Cement

UPV .... Ultrasonic Pulse Velocity

NDT .... Non-Destructive Testing

M25 .... Standard Concrete Grade

M40 .... Standard Concrete Grade

M25-RS .... Concrete made with natural river sand

M25-DMS . Concrete made with 100% replacement of natural river sand by dredged marine sand

M40-RS .... Concrete made with natural river sand

M40-DMS . Concrete made with 100% replacement of natural river sand by dredged marine sand

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Chapter 1

Introduction

1.1 General

Concrete is most widely used man-made construction material in the world, and is second only to water as the most utilized substance on the planet. It is obtained by mixing of cementing materials, water and aggregates, and sometimes admixtures,(Shown in Fig.1.1) in required proportions. In manufacturing of concrete aggregates provide about 75%of the body of concrete and hence its influence is extremely important. The most important function of the fine aggregate also assists the cement paste and hold the coarse aggregate particles in suspension. In manufacturing of concrete aggregates are generally obtained from natural deposits of sand and gravel, or from quarries by cutting rocks. Nowadays, these sources of natural aggregates are in the state of depletion and their extraction also has harmful consequences on the environment. For this reason, it is important to optimize the consumption of natural aggregates as well as to enhance their replacement by other alternative sources such as offshore sand, dune sand, quarry dust and washed soil which have also been made use for replacing the fine aggregate to minimize the use of natural river sand in concrete.[1]

One can think of an option of using Dredged marine sand (DMS) as fine aggre-

Figure 1.1: Basic components of Morden concrete.

gate which can, on the other hand be proved to be useful in maintenance of dredging activities for offshore structures or maritime structures. Marine aggregates offer an easier transport and the possibility of combining the desired size fractions, which can be a considerable advantage as compared to that of land-based aggregates. In this sense, maritime structures such as pavements represent a good alternative for technical, economic and environmental solutions using this kind of material.[1]

Fig 1.2 shows the dredged marine sand without sieving, at the time of using in concrte it should be sieve by 4.75 mm sieve. The dredged marine sand used in manufacturing of the concrete as a replacement of natural river sand was extracted from the South port area of Mundra port in Kutch district. Dredging works (enlarging and deepening access channels, achieving appropriate water depths along waterside facilities, etc.) are usually required in order to carry out maintenance activities in many ports all over the world. The dredging work mainly includes removing accumulated sediments from the bottom of dredged channels etc. is also necessary.[2]

Initially the primary investigation is done using the raw dredged marine sand and not the processed sand to see the behavior and effects of the sand in the concrete whether concrete works well with the row sand or not. Fig 1.3 Shows the dredger

Figure 1.2: Dredged marine sand

Namely Shanti Sagar XVI, which is built at IHC Merwede shipyard. This dredger is available at Mundra Port, Mundra Port and Special Economic Zone Limited (MPSEZ, India's largest private port and special economic zone will acquire the biggest cutter suction dredger ever.[2]

Figure 1.3: Shanti Sagar XVI built at IHC Merwede shipyard

.

Fig 1.3 shows the Cutter suction dredger which is right now used at Mundra port for dredging the marine sand and its details are given as follows. Details of the Cutter suction dredger shown in the Fig 1.3 with respect to its dimensions and dredging capacity are as follows.

- Name: SHANTI SAGAR XVI
- Type: Stationary Cutter Suction Dredger
- Year of construction: 2011
- Owner: Mundra Port Special Economic Zone Ltd. Length over all: 104 m
- Breadth: 18.60 m
- Depth: 5 m
- Maximum dredging depth: 29 m
- Diameter suction pipe: 900 mm
- Total installed power: 13 kW
- Accommodation: 26 people

The offshore sand extracted generally from below around 15 m of ocean depth would not affect the coastal sediment budget. It has been found that the dredging and pumping costs would be around 90% of the stockpiled sand cost and the transport cost is also not excessive as of natural river sand.[3]

There is a chain process till extracting to production.

- Extracting and loading into dredger.
- Discharging from the dredger machine.
- Storage near port.

- Transportation process.

Experimental studies for DMS extracted from European and American coasts have shown that these materials are suitable as construction material for the base and sub-base of pavements. Also, material from marine deposits around the coasts of Great Britain has been used in concrete production for several decades. [1]

In Britain this vital marine resource is growing in importance as a means of sustaining the built environment. In doing so, it contributes substantially to the quality of our lives. Over 21 million tons of marine sand and gravel is extracted from over 70 licensed areas around the coast of England and Wales each year.

One company namely The British Marine Aggregate Producers Association (BMAPA) supplies, Around 17% of the sand and gravel used in England and Wales is now supplied by the marine aggregates industry. It also makes a healthy contribution to our balance of payments through exports to the near continent. This company contributes Over 40 per cent of the sand and gravel produced in the South East area of Britain.

Figure 1.4: British Marine Aggregate Producers Association

Marine aggregates in concrete: The shape, strength and other physical characteristics are generally identical to high quality land-based aggregates and as such the end uses are no different. Their main use is in the manufacture of concrete, but they are also widely used in the production of:

- Asphalt and coated products.

- Masonry and paving blocks.
- Drainage and fill materials.
- Leisure and sport facilities.
- Industrial applications.

Marine sands in mortars and screeds: Marine sands have mechanical, chemical and physical properties identical to the high quality land-based sands and as such the end uses are no different. They are also widely used in the production of:

- Mortar for bricklaying and block making.
- Screeds.
- External renders.
- Internal rendering.
- Masonry blocks.
- Paving blocks.

Fig 1.5 shows the several examples given below which proves the successful use of marine aggregate in concrete structures. Other examples are the construction of Rotterdam Harbor (Netherlands), the Great Belt Bridge (between Denmark and Sweden), the Thames Barrier, London's National Theater, the Tamar Bridge of Plymouth (UK), The channel tunnel rail link, Chanary wharf station, The Severn bridge, Wibledon Stadium, Blue water shopping center. Outside Europe there are also remarkable constructions like the artificial island of Chek Lap Kok, where the Hong Kong Airport is located, The Palm Islands in Dubai.[1]

Figure 1.5: Example of Successful use of marine aggregate in concrete structures.

1.2 Research Significance

The importance of this study is to experiment and evaluate the effects of replacement of river sand with dredged marine sand (DMS) which can be proved to be a new material for construction activities. The effects with respect to mechanical and durability properties of concrete are to be studied.

Nowadays concrete is most importantly used material in almost all structures as a basic material. The sand which is taken generally from quarries or alluvial rivers is a basic ingredient for manufacturing the concrete. But At a time when land- based quarrying is under increasing environmental pressure, this vital marine resource is growing in importance as a means of sustaining the built environment. To counteract this problem some other sources have to be found out and studied as well as experimented.

The research is done mainly to determine if Dredged Marine Sand is used as a replacement of Natural River Sand in concrete, how the effects on concrete with respect to mechanical and durability properties differ as compared to concrete made with Natural River Sand.

If the investigation will allow the successful usage of the Dredged Marine Sand which replaces the Natural River Sand in concrete as a ne aggregate, we can minimize or eliminate the use of Natural River Sand and thus minimizing the harmful effects on environment by saving the source of river sand.

The modification in mechanical and durability properties are to be studied for concrete with 100% percentage replacement with DMS by RS.

So far the Dredged Marine Sand was only been used for the construction of the pavements, foundations, piles and sand filling in India. Furthermore, it could be more realistic and flexible in developing construction activities if this usage of marine sand is utilized and can be used in the construction of super-structures.

1.3 Objectives of study

To study the effects of dredged marine sand in concrete, following objectives are decided for major project work.

- To fulfill the design criteria in both M25 and M40 grades of concrete by using 25% fly ash and chemical admixture are used to achieve required workability criteria.

- To achieve required compressive strength using river sand as well as dredged marine sand for M25 and M40 grades of concrete are to be cast.

- To compare variation in compressive strength for M25 and M40 concrete grades made with 100% river sand and 100% dredged marine sand respectively with and without durability exposure.

- To study resistance to sulfate attack for M25 and M40 concrete grades made with 100% river sand and 100% dredged marine sand after exposure to sulfate for duration of 1, 3, 6, and 12 months, respectively.
- To evaluate resistance to chloride attack for M25 and M40 concrete grades made with 100% river sand and 100% dredged marine sand after exposure to chloride for duration of 1, 3, 6, and 12 months, respectively.
- To measure variation in permeability of M25 and M40 concrete grades with 100% river sand and 100% dredged marine sand with and without sulfate exposure for duration of 1, 3, 6, and 12 months, respectively.
- To find effect of chloride resistance for M25 and M40 concrete grades with 100% river sand and 100% dredged marine sand by RCPT test performed at intervals of 1, 3, 6, and 12 months, respectively.
- To conduct rapid chloride permeability test and permeability tests for slab panels are subjected to wet dry sea water exposure and made with 100% river sand and 100% dredged marine sand for M30 and M40 concrete grades.

1.4 Scope of work

The scope of work for the major project is mainly divided in to two parts which are as follows.

- (A) Investigation pertaining to Compressive strength of Both M25 & M40 Grade with Natural River Sand to Dredged Marine Sand:

The work is mainly focused on the studies of mechanical property i.e. compressive strength and durability properties of the concrete exposed to different exposures. Overall scope is presented in Figure **??** & Figure **??** respectively. For all four mixes control cured specimens are to be tested at 28 days, 3, 6 and 12 months, respectively.

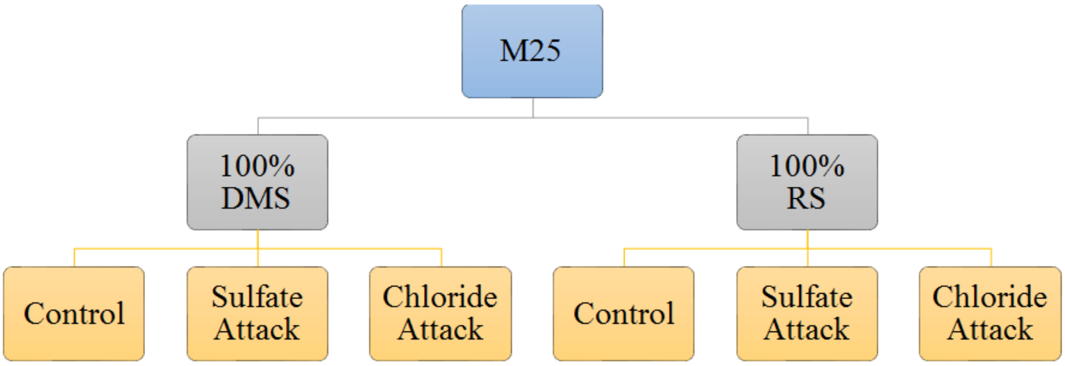

Figure 1.6: Scope for M25 Grade Concrete and Different Exposure condition

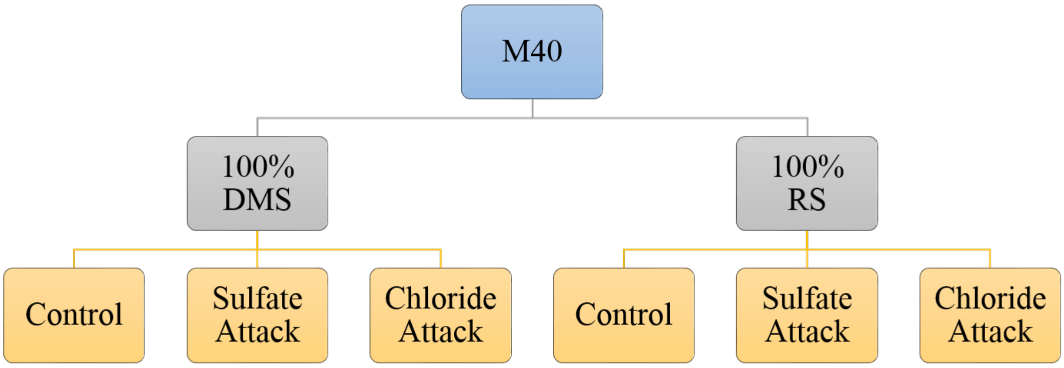

Figure 1.7: Scope for M40 Grade Concrete and Different Exposure condition

And for chloride and sulfate exposure tests specimens are to be tested at 1, 3, 6 and 12 months of exposure after 28 days of control curing.

Two concrete grades are taken into considerations which are M25 and M40 for the experimental work. Two different dosages of dredged marine sand are decided to be taken for the experiment i.e. 0% replacement and 100% replacement of dredged marine sand.

Overall 4 mixes are made for evaluating various parameters of concrete using dredged marine sand. It is planned to cast cubes of size 150 mm X 150 mm X 150 mm for the whole work. Average results of three cubes are to be taken for the final result. It is planned to cast total 60 cubes for evaluating the compressive strength of concrete for all mixes after 7, and 28 days of moist curing. For the durability aspects, total 144 cubes are to be cast for water absorption,and Rapid chloride permeability test respectively i.e. 96 cubes for water permeability test and 48 cubes for RCPT test. Further, for other durability properties 96 cubes are to be casted for sulfate and chloride resistance test of concrete i.e. 48 cubes per test.

Sulfate resistance test: Dosage for the sulfate exposure to concrete mixes is 5% Na_2SO_4 (sodium sulfate) of the total weight of water. Exposure ages are 1 months, 3 months, 6 months and 12 months, after 28 days of moist curing for all cubes. Change in compressive strength and change in mass are to be measured after completion of exposure at each age for concrete mixes.

Chloride resistance test: For this test, the content for the chloride exposure to concrete mixes is 3% NaCl (Sodium Chloride) of the total weight of water. Exposure ages are 1 months, 3 months, 6 months and 12 months, after 28 days of moist curing for all cubes. Change in compressive strength and change in mass are to be measured after completion of exposure at each age for concrete mixes.

Permeability test: For this test, 150mm$\times$150mm$\times$150mm cubes are to be cast for both grades. The specimen shall be thoroughly cleaned with a stiff wire brush to remove all laitance. The end faces shall then be sand-blasted or lightly chiselled. The specimen shall be surface-dried and the dimensions measured to the nearest 0.5 mm. It shall then be centred in the cell, with the lower end resting on the ledge.ith the system completely filled with water, the desired test pressure shall be applied to the water reservoir and the initial reading of the gauge-glass recorded.This test is performed on M25 and M40 concrete grades with 100% river sand and 100% dredged marine sand with and without sulfate exposure for duration of 1, 3, 6, and 12 months, respectively.

Rapid Chloride Penetration Test: For this test, 150mm×150mm×1500mm cubes are to be cast for both grades. as per standard size 100mm diameter and 50-75mm height core extracted from the cubes to measure chloride penetration in concrete. all the specimens are to be dried free of moisture before testing.RCPT test is performed on M25 and M40 concrete grades with 100% river sand and 100% dredged marine sand without exposure for duration of 1, 3, 6, and 12 months, respectively.

It is also planned to observe the variation in appearance of immersed concrete specimens after completion of the designated exposure in all two chemicals.

- (B) Investigation pertaining to testing of core specimens extracted from R.C.C Slab Panel:

This part includes the extraction of cylindrical specimens of concrete from slab panels of M30 & M40 grade concrete. For each grade two slab panel were cast using DMS and RS. all slab panels were exposed to alternate drying and wetting condition for 140 days in sea water.

For this study, Total 24 cores of 127mm diameter are extracted for both compression and water permeability test. and 12 cores of 101mm diameter are extracted for RCPT Test.

Slab Panel

M40	M30
•100% RS •3 Cores for Compression •3 Cores for Permeability •3 Cores for RCPT •100% DMS •3 Cores for Compression •3 Cores for Permeability •3 Cores for RCPT	•100% RS •3 Cores for Compression •3 Cores for Permeability •3 Cores for RCPT •100% DMS •3 Cores for Compression •3 Cores for Permeability •3 Cores for RCPT

Figure 1.8: Scope for Core Testing

Before compression test all possibly non-destructive test were conducted on the core specimen like carbonation test, ultrasonic pulse velocity and strength assessment test are to be performed.Figure 1.8 shows the overall scope of core testing.

Three cores each from panels having dimension 228mm height and 127mm diameter are to be extracted for the compression test.i.e 3-cores from M30 NRS & DMS panel, 3-cores from M40 NRS & DMS panel, respectively.

Three cores each from panels having dimension 228mm height and 127mm diameter are to be extracted for the Water Permeability Test.i.e 3-cores from M30 NRS & DMS panel, 3-cores from M40 NRS & DMS panel.

Three cores each from panels having dimension 228mm height and 101mm diameter are to be extracted for the Rapid Chloride Penetration Test(RCPT).i.e 3-cores from M30 NRS & DMS panel, 3-cores from M40 NRS & DMS panel.

Average result of three cores is to be considered as a final result in terms of variation in above parameters.

1.5 Layout of report

The report of the major project is mainly classified into five chapters which are given as below.

Chapter 1 shows the discussion about the general overview and the significance of the project and also having the objectives & scope of work for the experiment.

Chapter 2 describes literature review which is having mostly the research work pertaining to this project done in past. It includes properties of dredged marine sand, percentage replacement and their effects on mechanical and durability properties of concrete and applications of dredged marine sand in concrete as a fine aggregate.

Chapter 3 discusses about the whole tests conducted before starting the experimental work in detail. The chapter is having concrete mix design, properties of material used in the casting work, & whole process of all the tests.

Chapter 4 discusses about the experimental in detail. The chapter is having casting of concrete,Extraction of core specimens, whole casting work details and the process of all other durability tests.

Chapter 5 includes all the results and discussions with respect to the mechanical properties as well as durability properties. The mechanical properties include compressive strength for different ages of curing. Durability properties such as sulfate resistance, chloride resistance, water absorption test and rapid chloride penetration test are also taken into consideration.

Chapter 6 is having the concluding remarks, summary of the whole project and the future scope of work for the major project work.

Chapter 2

Literature review

2.1 General

This chapter explains the brief understanding of how the usage of dredged marine sand can be utilized as an alternative material instead of the natural river sand as fine aggregate in manufacturing of concrete. It mainly includes the research work as well as experiments done in past, the allowable dosage, mechanical and durability aspects, mineralogical, physical & chemical properties of dredged marine sand.

2.2 Studies on Mechanical and Durability properties of concrete with dredged marine sand

2.2.1 Physical, Chemical and Mineralogical properties of Fine Aggregate

Limeira et al.[2] described the experimental work on three different sections and with three different concretes. The influence of dredged marine sand (DMS) from Port of Sant Carles de la Rpita (Tarragona, Spain) as a fine aggregate on the production of concretes was analyzed, and its properties were determined.

The study presented the physical, chemical and mineralogical properties of the DMS which was extracted from the Port of Sant Carles de la Rpita (Tarragona, Spain) and stockpiled in the open air for 3 months. Then after five representative samples of 1 m3 of DMS from different locations and submitted to sampling in order to determine the above properties. The grading of DMS, determined according to UNE-EN 933-1 specifications.

Grading of the DMS as compared to regular sand and Coarse aggregate is shown in Fig 2.1.

Fig 2.1 shows the physical characterization showed that the DMS used in this re-

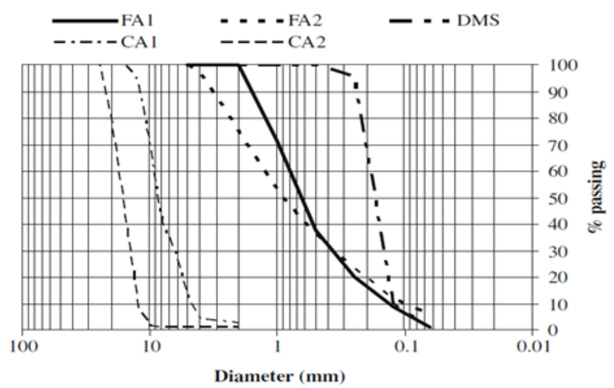

Figure 2.1: Grading curves of fine and coarse aggregates

search work presented a considerable content of high fine particles with more than 95% of the material passing through 0.25 mm according to the sieve analysis.

Molina et al. [1]had given the grading of the DMS samples. The samples for testing were obtained by sampling 1 m3 of each DMS extracted from two stockpiles of the harbor site of the Port of Barcelona.. In order to determine possible contaminant components, exhaustive sampling was carried out according to the UNE-EN 932-1 specification. The results are given in the Fig 2.2.

Hafiz [11]had tested the sample of Sea sand (DMS) extracted from the Dungun,

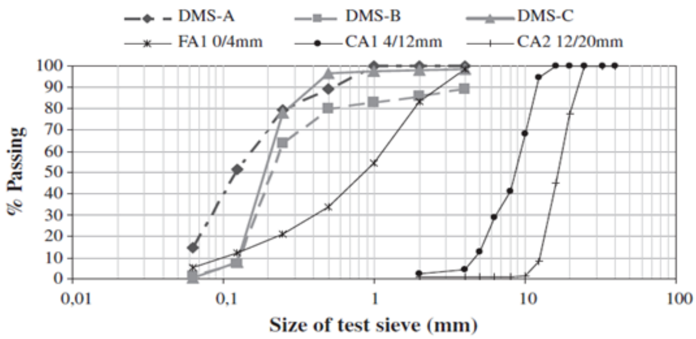

Figure 2.2: Grading curves of aggregates

Beach at Terengganu and the results for the grading of that sample is shown in Fig 2.3. The abundant sea sand has been sieved by Sieve Analysis of Fine and Coarse Aggregate is based on ASTM C 136 - 05.

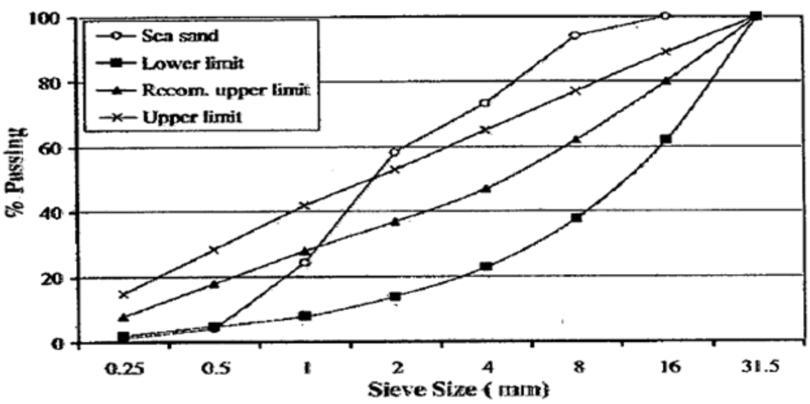

Figure 2.3: Sieve analysis results of fine aggregate

Dias et al. [3]described the shell contents in the offshore sand which has been taken from North of Colombo, Sri Lanka. The fine aggregate grading tests were carried out as per BS 812-103.1: 1985(2000). 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 and dissolving in HCl for the latter. The shell content was measured for coarse, medium, fine and typical grading of offshore sand, from a sample size of 1000 g.

Grading of the fine aggregate and the shell contents (%) in offshore sand are given in Table 2.1 and Table 2.2 respectively.

Table 2.1: Grading of offshore sand

Characteristic	Offshore sand types			
	Typical	Coarse	Medium	Fine
<0.60 mm (%)	44	42	49	85
<0.15 mm (%)	2.6	2.5	2.7	12
D_{50} (mm)	0.63	0.66	0.60	0.21

Table 2.2: Shell contents (%) in offshore sand

Grading	Fraction	
	<5 mm	>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 2.1 shows the grading of the offshore sand characterized in test which indicates a high D50 value of 0.6 mm, which makes it very suitable for concrete production and also for quick draining of seawater.Subsequently Table 2.2 describes the shell content of offshore sand which was also within BS 882 limits.

Limeira et al. [2] had given the results of chemical and mineralogical identification in the test results which also give the heavy metals in g/g in DMS samples. Such properties are given in Table 2.3 & 2.4, respectively. Minerals are given in three categories as Major component, Secondary component and Minority components.

Table 2.3 shows that DMS samples are having the components Calcite $CaCO_3$ and Quartz SiO_2 as major and secondary component respectively and all other minerals as minority.

Table 2.3: Mineralogical properties of dredged marine sand by X-ray diffraction

Mineral	1	2	3	4	5
Calcite $CaCO_3$	××	××	××	××	××
Quartz SiO_2	×××	×××	×××	×××	×××
Halite NaCl	×				×
Dolomite $MgCa(CO_3)_2$	×	×	×	×	×
Mica Muscovite $KMgAlSi_4O_{10}(OH)_2$	×	×	×	×	×
Albite $NaAlSi_3O_8$	×	×	×	×	×
Sanidina $(Na, K)AlSi_3O_8$		×	×	×	×
Hidrofilita $CaCl_2$	×				×
Orthoclase $KAlSi_3O_8$			×	×	
Carolinian $Al_2Si_2O_5(OH)_4$	×	×	×	×	×
Silvina KCl					×
Relation of maximum intensity picks calcite/quartz	25/100	12/100	25/100	33/100	24/100

Key: ×××, major components; ××, secondary components; ×, minority components or possible.

Table 2.4: Heavy metals in DMS samples

Heavy metals (μg/g) in DMS samples.

Samples	Cd	Cu	Zn	Cr	Ni	As	Hg	Pb
1	0.08	1.85	22.21	30.43	20.98	3.53	nd	60.26
2	0.08	2.49	31.65	18.61	8.73	3.62	0.01	nd
3	0.07	2.88	23.9	29.64	12.17	3.57	0.02	114.28
4	0.07	4.12	27.29	35.93	12.38	3.4	0.02	101.98
5	0.01	8.24	26.3	34.2	8.65	3.4	0.06	89.01
Level of action 1	1	100	500	200	100	80	0.6	120

Rodica and Lupinca [12] had investigated the mineralogical properties of the river sand from the Timis river. The properties are given in Table 2.15.

The Table 2.15 concludes that the content of leachate parts of the sand from Timis is under 1.5%. The content of SiO2 smaller than 90% of the sand situates it in the category of weak sands. And also the total content of Quartz and Feldspar should be more than 90% which is not the case here for this river sand.
Basack and Purkayastha [7] determined the engineering properties of the marine clay collected from Visakhapatnam, India. In the investigation physical, chemical and mineralogical properties were determined. And they have given the Sp. Gravity of marine clay which was 2.62.

Table 2.5: Mineralogical properties of river sand of Timis river

Mineralogical composition	%
A. Basic constitutive materials	
Quartz (SiO_2) (metamorphic + magnetic, rolled) Partially colonized	80
Feldspar ($KAlSi_3O_8$,$NaAlSi_3O_8$)	3
Muscovite KAl_2 $(OH_3F)_2(AlSi_3O_{10})$	5
Garnet-Almandine $Fe_3Al_2(SiO_4)_3$	
Spessartine $(Mn,Fe)_3Al_2(SiO_4)_3$	3
B . Secondary materials	
Biotite, partially with chloride $K(Mg,Fe,Mn)_3(OH_3F)_2AlSi_3O_{10}$	2
Chlorite $(Mg,Al)_3OH_2(AlSi_3O_{10})Mg_6(OH)_6$	1
Magnetite (Fe_3O_4)	2
Ilmenite ($FeTiO_3$)	1
Apatite $CaF(PO_4)_3$	0,5
Titan $CaTi(SiO_3)$	0,5
Rutile (TiO_2)	0,3
Tourmaline $NaFe_3Al_6(OH)_4(BO_3)_3Si_6O_{13}$	0,5
Hornblende	0,5
Zircon Zr $(SiO)_4$	0,2
Cyanide Al_2 (SiO_3)	0,5

2.2.2 Fresh Concrete

Limeira et al. [1] had given the results of slump test of different concrete mixes. The details of concrete mixes taken in experiment and their slump test results in cm are given in the Table 2.6. Slump test was performed as per UNE-EN 83-313-90 standard.

Table 2.6 indicates that the fresh properties of the concretes using DMS in partial substitution of raw sand 0/4 mm were similar to those of the control mixture, with the dry consistency required for the design of concrete pavements.

Limeira et al. [2] had done experiment based on three different sections of a harbor pavement made with three different concretes. The three concretes were produced at a homologated plant (UNILAND): C1 (control concrete), C2 (concrete made with

Table 2.6: Slump test results

Concrete	Nomenclature	Slump (cm)
Reference concrete	RC	1.0
Concrete with 15% DMS-A	CA15%	0.0
Concrete with 25% DMS-B	CB25%	1.0
Concrete with 35% DMS-B	CB35%	3.0
Concrete with 35% DMS-B	CB50%	1.5
Concrete with 25% DMS-C	CC25%	2.0
Concrete with 35% DMS-C	CC35%	1.5
Concrete with 50% DMS-C	CC50%	1.5

DMS as corrective fine sand) and C3 (concrete made with DMS as corrective fine sand and reinforced with plastic fibers PF).The slump test (by Abrams cone) was carried out at casing time for the construction of pavements. The results of slump test are given in Table 2.7. The results of slump test in the experiment shows that the

Table 2.7: Slump test results of concrete for pavement

Concrete mix	Slump (cm)
C1	17
C2	22
C3	19

properties of fresh concrete using DMS in substitution of fine sand i.e. C2 and C3, were similar to those of control concrete C1. An acceptable fresh concrete consistency was achieved in both cases.

Wang et al. [?] had examined the durability of self-consolidating lightweight aggregate concrete (SCLAC) made from dredged silt from reservoirs in South Taiwan. The slump test was done to determine the property of fresh concrete. The results were taken for freshly cast concrete i.e. initial slump and reading after 60 minutes. The results are shown in Table 2.8. The results of slump test in Table 2.8 shows that fresh

Table 2.8: Results of initial slump and slump after 60 minutes

Initial slump (cm)	Slump after 60 minutes (cm)
26-27	51-58

self-consolidating lightweight aggregate concrete can meet the requirements of high flowability and slumping time, depending on the concrete. Slump and slump flow of SCLAC reaches 26-27 cm and 51-58 cm, respectively.

2.2.3 Hardened concrete

Limeira et al. [2] described three experimental sections of a harbor pavement made with three different concretes. Fine aggregate which was used in the experiment was extracted from Port of Sant Carles de la Rpita (Tarragona, Spain). Concrete grade which was considered was M30. Three different mixes were considered in the investigation which are C1 (control concrete), C2 (concrete made with DMS as corrective fine sand) and C3 (concrete made with DMS as corrective fine sand and reinforced with plastic fibers PF).The properties of the test specimens were determined after 28 days of moist curing of all the specimens. The results of mechanical properties i.e. compressive strength are given in the Table 2.9.

The results of mechanical properties show that the mechanical properties (compressive strength) of concretes made with DMS in substitution of fine sand i.e. C2 and C3 were nearly similar to those in the control concrete. Concrete C3 made with DMS in substitution of fine sand and PF incorporation obtained lower mechanical properties than the control concrete at 28 days of curing. This effect can be attributed to the

Table 2.9: Mechanical properties of all concrete mixes after 28 days for M30 grade

Concrete	Compressive strength (MPa)
C1	39 (5%)
C2	36 (4%)
C3	33 (5%)

higher plasticizer content and the presence of polypropylene fibers.

Agullo et al. [1] studied the mechanical and durability properties of concretes fabricated with dredged marine sand (DMS) as a fine granular corrector in partial substitution of raw sand (from 15% to up to 50% by raw sand mass) designed for harbor pavements. Three fractions of crushed limestone raw aggregates were considered i.e. fine aggregate FA1 0/4 mm, coarse aggregate CA1 4/12 mm and CA2 12/20 mm. Three DMS from the Port of Barcelona were used in partial substitution of FA1. Details of concrete mixes are given in Table 2.6. Concrete mix proportions are given in Table 2.10 and Mechanical properties of all concrete mixes are given in Table 2.11.

Table 2.10: Concrete mix proportion of all concrete mixes

	RC	CA15%	CB25/CC25%	CB35/CC35%	CB50/CC50%
CA2 12/20 mm (kg)	755	755	755	755	755
CA1 4/12 mm (kg)	243	243	243	243	243
FA1 0/4 mm (kg)	896	762	672	582	448
DMS (kg)	0	134	224	314	448
Cement (kg)	329	329	329	329	329
Water (kg)	145	145	145	145	145
Plasticizer (% of cement weight)	0.6	2.6	1.5	2.3	2.6

Table 2.11: Mechanical properties i.e. compressive strength of all concrete mixes

	7 days	28 days
RC	32	35
CA15%	30	33
CB25%	30	35
CB35%	31	40
CB50%	37	39
CC25%	30	41
CC35%	31	38
CC50%	35	40

Mechanical properties i.e. compressive strength and physical properties of the concretes made with DMS in substitution of crushed limestone sand were similar to those of the reference concrete RC. The results also indicate slight increase in compressive strength of concrete CC25% after 28 days as compared to other concrete mixes.
Dias et al. [3] performed the experiment using offshore sand for the reinforced concrete. The offshore sand has been taken from North of Colombo, Sri Lanka and 5 km to 10 km off the Western Coast of Sri Lanka. The results were described about the mechanical and durability properties of the reinforced concrete in this research work. Type of cement which was used in manufacturing work of the concrete was ordinary portland cement. The offshore sand used as a fine aggregate in concrete was having different chloride contents for three concrete grades which are given in Table 2.12.

Mechanical properties i.e. compressive strength of the concrete with concrete mix proportion is shown in Table 2.13. This table also shows the properties of fresh concrete i.e. measured slump for all concrete grades.

Table 2.12: Chloride content for all concrete grades

Grade of concrete	Chloride content
20	0.076
25	0.086
30	0.096

2.2.4 Durability of concrete

Etxeberria et al. [2] suggested the use of DMS in the harbor pavement construction for three concrete mixes. DMS was extracted from Port of Sant Carles de la Rpita (Tarragona, Spain). Three concrete mixes were C1 (control concrete), C2 (concrete made with DMS as corrective fine sand) and C3 (concrete made with DMS as corrective fine sand and reinforced with plastic fibers PF). These C1, C2 and C3 show the actual specimens. Three cylindrical cores T1, T2 and T3 of 100 mm diameter and 200 mm height were also taken from the specimens and sent for the durability tests.The capillary suction curves of T1, T2 and T3 are illustrated in Fig 2.4 and the corresponding absorption coefficients as well as results of water absorption (%) are summarized in Table 2.14.

Table 2.13: Concrete mix proportions and results of compression test of all mixes

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
Sand/cement ratio	2.92	2.47 (2.55)	2.25
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 2.14: Results of capillary absorption test and water absorption test for all concrete mixes

Concrete mix	Capillary absorption coefficient (cm/h$^{1/2}$)	Absorption (%)
C1	0.0441	-
C2	0.0558	-
C3	0.0632	-
T1	0.0274	5.9
T2	0.023	5.5
T3	0.0236	5.6

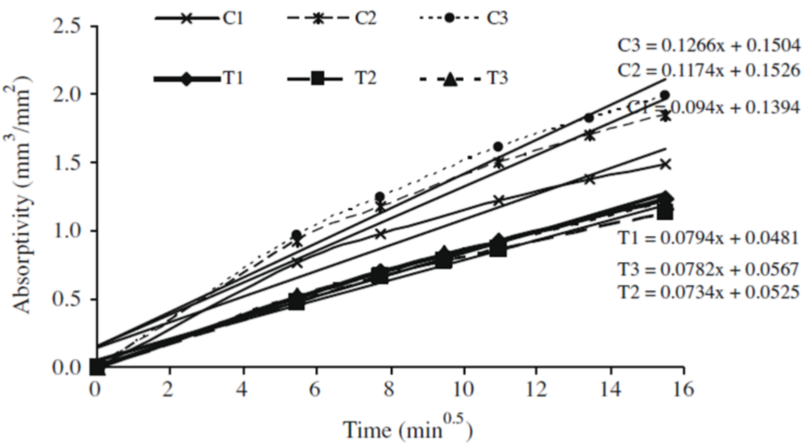

Figure 2.4: Capillary suction curves in the first 4 hrs for C1, C2 and C3 specimens and T1, T2 and T3 cylindrical cores

The results of the experiment show that the concrete made with DMS i.e. C2 and C3 show the higher values of capillary absorption coefficient for the results related with test specimens, whereas the results for the same test are low for cylindrical cores. Absorption (%) for cylindrical cores less for C2 as compared with the concrete mix C3 and C1.

Limeira et al. [1] studied the different durability parameters of concrete using DMS of different dosage varies from 15% to 50% replacement of river sand with DMS. Three types of DMS materials in partial substitution of crushed limestone raw sand were used in the investigation. Sorptivity test was done in the experimental work and following Table **??** and Fig 2.5 show the results of sorptivity test. DMS-A sample was discarded because the Cl^- content was exceeding the limit in this sample.

Table 2.15: Sorptivity test results

Concrete mix	Sorptivity (mm/min$^{1/2}$)
RC	0.060
CB35%	0.059
CB50%	0.058
CC35%	0.046
CC50%	0.056

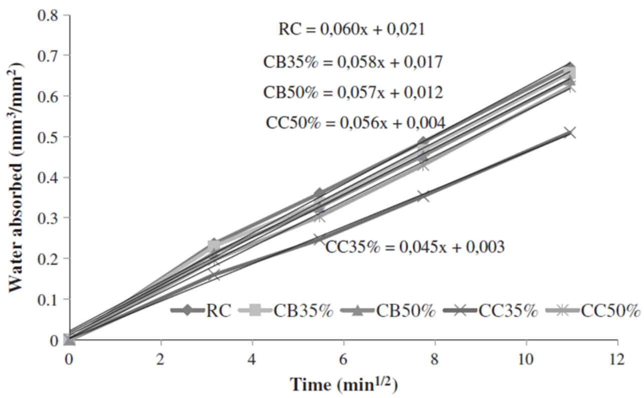

Figure 2.5: Capillary suction curves in concrete mixes in first 2 hrs

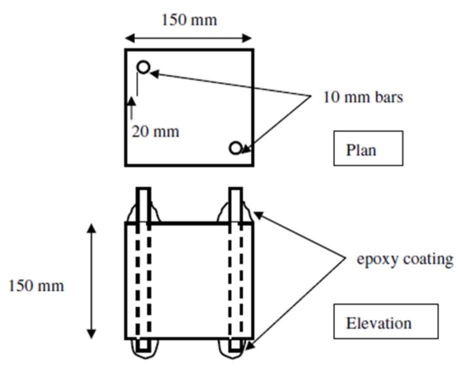

Figure 2.6: Accelerated corrosion test specimen

Four specially fabricated 150 mm cube moulds were used so that two mild steel bars of 10 mm diameter could be embedded in each cube. 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. Fig 2.6 shows the details of the specimen. 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. After 1 day of casting and again 1 day of drying, the part of the bar which is outside of specimen at top and bottom, were coated with epoxy as shown in Fig 2.6.

Two of the specimens were left to dry until an age of 14 days, after which they were placed in a carbonation chamber that was initially filled with CO_2 and subsequently re-filled each time the chamber was opened to take half-cell potential readings. 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.

Half-cell potential readings were measured at the top, middle and bottom of each specimen initially at weekly interval for the specimen in carbonation chamber and twice weekly for specimens in NaCl solution.

The results of the half-cell potential for the specimen in NaCl bath are given in Fig. 2.7 and for specimens in carbonation chamber (100% CO_2) are given in Fig 2.8.

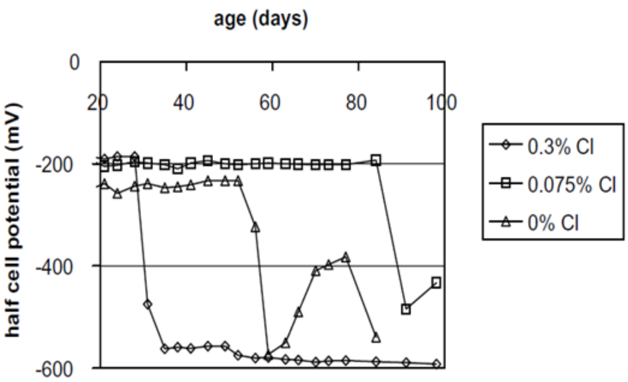

Figure 2.7: Half-cell potential readings for specimens in NaCl bath

In Fig 2.7 three different mixes were considered i.e. concrete with sand having allowable Cl^- content of 0.075%, concrete mix with sea-water saturated sand having Cl^- content of 0.3% and concrete mix free from Cl^- content. and half-cell potential readings are shown in Fig 2.8.

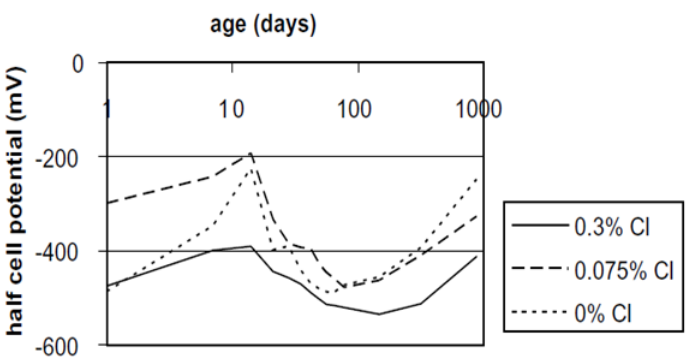

Figure 2.8: Half-cell potential for specimens in carbonation chamber (100% CO_2)

The corrosion performance concrete mix 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 significant corrosion in embedded steel.

2.3 Applications

Marine sands are the finer fractions of the aggregate deposits found on the inner continental shelf off the UK coast. Marine sands have mechanical, chemical and physical properties identical to the high quality land-based sands and as such the end uses are no different. They are also widely used in the production of: [15]

1. Mortar for bricklaying and blockmaking
2. Screeds
3. External renders
4. Internal rendering
5. Masonry blocks
6. Paving blocks

Application of marine sand related with the beach nourishment and shorelines are very often in Ostia (Rome). In Fig 2.9, some phases of the nourishment work of shorelines in Ostia (Rome) are shown using marine sand.[16] Other important applications which are done in Ostia (Rome) are as follows:

- National parks and blue oases
- Areas for the dumping of harbor materials
- Cables and pipes
- Offshore terminals which are not permitted for anchorage and fishing

Figure 2.9: Phases of nourishment of shorelines in Ostia (Rome)

- Artificial barriers and military shooting-range, as well as the belt within 3 nautical miles away of the coastline
- Intertidal feeding / creation, e.g. islands for birds, mudflat and salt marsh creation, fisheries habitat and wetland restoration.

EMSAGG seminar at Turkish chamber of shipping at Bob dean university of Florida had discussed about the engineering use of marine sand in coastal projects. They proposed the use of marine sand as follows.[13]

- Offshore environment such as corals, fish, reefs etc.
- Onshore environment such as increase and/or redistribute wave energy.
- Construction: concrete roads and landfills
- Manufacturing glass and other products
- Beach nourishment

Fig 2.11 and 2.12 show the images of Miami beaches before and after nourishment using marine sand

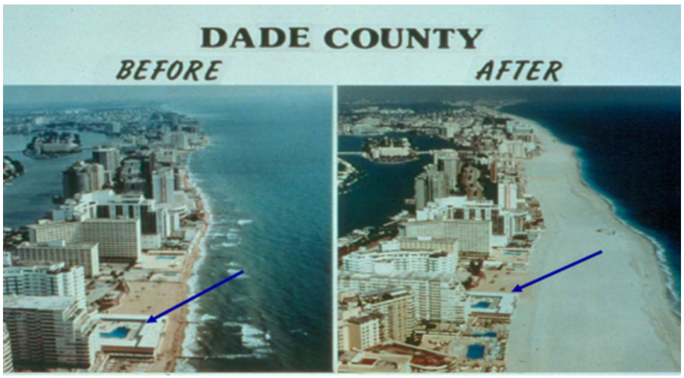

Figure 2.10: The Beach nourishment: 1976-1981

Figure 2.11: Miami beach before nourishment

Dias et al. [3] reported the experiment on offshore sand for reinforced concrete. They explained about the economic aspects of offshore sand in the concrete. In that they suggested to use offshore sand as a viable alternative of river sand in manufacturing of concrete. Because offshore sand extracted from below around 15 m of ocean depth (i.e. beyond the surf zone) would not affect the coastal sediment budget. It has been found that the dredging and pumping costs would be around 90% of the stockpiled sand cost; transport costs from the stockpile would not be excessive as the sand is meant to service the construction boom in the commercial capital of Colombo, which is just 15 km away.

Figure 2.12: Miami beach after nourishment

2.4 Summary

The chapter deals with the basic overview of research work which was done in the past with respect to dredged marine sand as a viable replacement of river sand in concrete and showed decent results when used in concrete & tested for concrete's mechanical and durability properties such as compressive strength and water absorption, & accelerated corrosion test respectively.

Chapter 3

Concrete Mix Design

3.1 General

The chapter describes the Concrete Mix Design which have been used in experimental work. Further methods followed for the casting and curing of the concrete specimens are given. Different types of materials used and tests with results are explained in detail in this chapter.

3.2 Cement

The cement commonly used is Ordinary Portland Cement, and the fine and coarse aggregates used are those that usually obtainable, from nearby sand, gravel, or rock deposits.In order to obtain strong, durable and economical concrete mix;it is necessary to understand the characteristics and behavior of the ingredients. Physical and Chemical Properties of cement are Given in Table 3.1 & Table 3.2.

Table 3.1: OPC 53 Grade Cement : Chemical Testing

OPC 53 Grade Cement : Chemical Testing				
SN	Particular	Test Results Obtained	Requirement of IS 12269:2013	
1	Lime Saturation Factor (LSF)	0.92	0.80 to 1.02	
2	Alumina to Iron Oxide Ratio %	1.25	0.66	Min.
3	Ilsolubne Residue	0.95	4	Max.
4	Mggnesia - MaO (% by mass)	3.6	6	Max.
5	Sulphuric Anhydride (% by mass)	2.77	3.5	Max.
6	toTal loss on ignition (% by mass)	1.81	4	Max.
7	Maximum Chloride (% by sasm)	0.045	0.1	for N.C
			0.05	for P.C

Table 3.2: OPC 53 Grade Cement : Physical Testing

OPC 53 Grade Cement : Physical Testing				
1	Finess (Blaine)			
	Specific Surface (meter square per kg)	300	225	Min.
2	Setting Time			
	Initias (Minutel)	105	30	Min.
	Finla (Minutes)	200	600	Max.
3	SoundnBss: Expansion ey			
	Le-Chmtelier Method (me)	1	10	Max.
	Auto-elavC(percent)	0.13	0.8	Max.
4	Compressive Strength (Mpa)			
	3 days	36.2	27	Min.
	7 days	46.3	37	Min.
	28 days	U.T	53	Min.

3.3 Fly ash

Fly ash is mainly used for reducing the cement content and it is also known as a mineral admixture in concrete. Two classes of fly ash are defined by ASTM C618: Class F fly ash and Class C fly ash. The chief difference between these classes is the amount of calcium, silica, alumina, and iron content in the ash. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned.i.e., anthracite, bituminous, and lignite. properties of fly ash is given in table 3.3

Table 3.3: Physical properties of fly ash

Fineness (Blaine)		
Specific Surface (m2/kg)		367
Specific Gravity (gm/cc)		1.96

3.4 Coarse Aggregate

The aggregates most of which are retained on the 4.75 mm IS sieve and contain only that much of fine material as is permitted by the specifications are termed Coarse Aggregates.The coarse aggregates may be one of the following types:

- Crushed gravel or stone obtained by the crushing of gravel or hard stone.
- Uncrushed gravel or stone resulting from the natural disintegration of rock.
- Partially crushed gravel or stone obtained as a product of the blending of the above two types.

The graded coarse aggregate is described by its normal size, i.e.,40mm, 20mm, 12.5mm,and 10mm.For example, a graded aggregate of nominal size 20 mm means an aggregate most of which passes the 20 mm IS sieve. For experimental programme same Mix design used. In that maximum aggregate size is 20mm used and 10mm aggregates are the minimum size of coarse aggregates. Gradation of 20mm Aggregate is shown in Table 3.5,Gradation of 10mm Aggregate is shown in Table 3.4, and All in aggregates test results are in Table **??**.

Table 3.4: Gradation of Coarse aggregate(20 mm)

Sieve Size	Mass Retained (gms)	% of Mass retained	Cumulative % of Mass retained	Cumulative % of Passing
80 mm	0.0	0.0	0.0	100.0
40 mm	0.0	32.0	0.0	100.0
20 mm	640.0	32.0	32.0	68.0
10 mm	1280	64.0	96.0	4.0
4.75 mm	80.0	4.0	100.0	0.0
2.36 mm	0.0	0.0	100.0	0.0
1.18 mm	0.0	0.0	100.0	0.0
600	0.0	0.0	100.0	0.0
300	0.0	0.0	100.0	0.0
150	0.0	0.0	100.0	0.0
Lower than 150	0.0	0.0	-	0.0
Total	2000	100	728	
Fineness Modulus = 728/1000 = 7.28				

Table 3.5: Gradation of Coarse aggregate(10 mm)

Sieve Size	Mass Retained (gms)	% of Mass retained	Cumulative % of Mass retained	Cumulative % of Passing
80 mm	0.0	0.0	0.0	100.0
40 mm	0.0	0.0	0.0	100.0
20 mm	0.0	0.0	0.0	100.0
10 mm	51.0	5.1	5.1	94.9
4.75 mm	913.0	91.3	96.4	3.6
2.36 mm	36.0	3.6	100.0	0.0
1.18 mm	0.0	0.0	100.0	0.0
600	0.0	0.0	100.0	0.0
300	0.0	0.0	100.	0.0
150	0.0	0.0	100.0	0.0
Lower than 150	0.0	0.0	-	0.0
Total	1000	100	601.5	
Fineness Modulus = 601.5/100 = 6.01				

Table 3.6: all-in aggregate gradation as per IS 383

Type of Material : Coarse aggregate & Fine aggregate					
Sieve Size		Coarse Aggregate	Fine Aggregate	Combine Passing (%)	IS 383 Table-4
40		100	_	100	100
20		97.28	_	97.28	95 - 100
4.75		2.59	34.51	37.1	30 - 50
600		_	26.98	26.98	10 - 35
150		_	3.96	3.96	0 - 6

3.5 Natural River Sand

It is the aggregate most of which passes through a 4.75mm IS sieve and contains only that much coarser material as is permitted by the specifications.Sand is generally considered to have a lower size limit of about 0.07mm.Material between 0.06mm and 0.002mm is classified as silt, and still smaller particles are called clay. The soft deposite consisting of sand,silt and clay in about equal proportions is termed loam.the fine aggregate maybe one of the following types:

- Natural sand,i.e., the fine aggregate resulting from natural disintegration of rock and/or that which been deposited by stream and glacial agencies.
- Crushed stone sand,
- Crushed gravel stone,i.e., the fine aggregate produced by crushing natural gravel.

According to size, the fine aggregate may ne described as coarse, medium, and fine sands.Depending upon the particle size distribution, IS:383-1970 has divided the fine aggregate into four Grading Zones. The grading zones becomes progressively finer from grading zone I to grading zone IV. The sieve analysis results are shown in Table 3.8 for natural river sand.

Table 3.7: Sieve Analysis of Natural River Sand

Sieve Size	Mass Retained (gms)	% of Mass retained	Cumulative % of Mass retained	Cumulative % of Passing
80 mm	0.0	0.0	0.0	100.0
40 mm	0.0	0.0	0.0	100.0
20 mm	0.0	0.0	0.0	100.0
10 mm	0.0	0.0	0.0	100.0
4.75 mm	0.0	0.0	0.0	100.0
2.36 mm	192.0	19.2	19.2	80.8
1.18 mm	215.0	21.5	40.7	59.3
600	77.0	7.7	48.4	51.6
300	362.0	36.2	84.6	15.4
150	117.0	11.7	96.3	3.7
Lower than 150	37.0	3.7	-	0.0
Total	1000	100	245	
Fineness Modulus = 245/100 = 2.45 and Zone II				

Table 3.8: IS Limitation For Zone Identification

Sieve Size (mm)	% Passing	Limit As per IS:383 Table:IV		
10	100	100	100	100
4.75	100	95 - 100	90 - 100	90 - 100
2.36	80.8	95 - 100	85 - 100	75 - 100
1.18	59.3	90 - 100	75 - 100	55 - 90
0.600	51.6	80 - 100	60 - 79	35 - 59
0.300	15.4	15 - 50	12 – 40	8 – 30
0.150	3.7	0 - 15	0 - 10	0 - 10
		Zone-4	Zone-3	Zone-2

3.6 Dredged Marine sand

3.6.1 Physical properties of dredged marine sand

The test is performed to determine the fineness and zone of the sand. Results are given in Table 3.8 and Table 3.9 respectively.

Table 3.9: Sieve Analysis of Dredged Marine sand

Sieve Size	Mass Retained (gms)	% of Mass retained	Cumulative % of Mass retained	Cumulative % of Passing
80 mm	0.0	0.0	0.0	100.0
40 mm	0.0	0.0	0.0	100.0
20 mm	0.0	0.0	0.0	100.0
10 mm	0.0	0.0	0.0	100.0
4.75 mm	175.0	175.0	17.5	82.5
2.36 mm	135.0	310	31	69
1.18 mm	98.0	408	40.8	59.2
600	119.0	527.0	52.7	47.3
300	248.0	775.0	77.5	22.5
150	177.0	952	95.2	4.8
Lower than 70.0	1000.0	100.0	-	0.0
Total	1000	100	285	
Fineness Modulus = 285/100 = 2.85 and Zone II				

Table 3.10: Results for various parameters for dredged marine sand

Type of Sand	Parameter	Test Results
Dredged marine sand	Fineness modulus	2.85
Dredged marine sand	Zone	II
Dredged marine sand	Specific gravity	2.56

3.6.2 Chemical properties of marine sand

The chemical properties of sand are investigated by two other laboratories and results are presented in Table3.10 and 3.11 respectively. Sample taken for test = 35 kg, Moisture condition when received = Surface dry.

Table 3.11: Chemical analysis results provided by Geo Test house

Chemical analysis results provided by Geo Test house				
Sr No.	Test Name	Test Method	Test Result	Specification requirement (IS 383-1970)
1	Organic Content	IS 2386: Part-2	Not detected	-
2	Chloride (%)	B.S.812:P-117	0.034	Max 0.04%
3	Sulfur as SO3	B.S.812:P-118	0.794	Max 0.05%
4	Presence of deleterious material(%)	IS 2386: Part-2 Cl-2 & 3	6.847	Max 5%
5	Volcanic solids	IS 3025: P-18	0.084	-

Table 3.12: Chemical analysis related with Alkali aggregate reactivity provided by K.C.T. Consultancy

Results of chemical analysis related with Alkali aggregate reactivity provided by K.C.T. Consultancy Services		
No.	Alkali aggregate reactivity test	Fine aggregate
1	Reduction in alkalinity (milimol/1)	132.19
2	Silica dissolved from 300 micron meter size aggregate material (milimol/1)	1.78

Table 3.13: Results of chemical test for deleterious material of marine sand provided by K.C.T. Consultancy

No.	Test description	Results(%)	Requirement as per IS 383(%)
1	Coal and Lignite	Nil	Max 1%
2	Clay lumps	Nil	Max 1%
3	Material finer than 75 micron	1.5	Max 3%
4	Shale	6.6	Max 1%
5	Total % of all deleterious material	8.1	Max 5%

3.7 Super plasticizer

There are two different concrete grades which were recognized in the experimental work i.e. M25 and M40. For M40 concrete grade, super plasticizer has been utilized for accomplishing obliged workability of the concrete. Master Polyhead 8981 was utilized as an admixture to enhance workability of the fresh concrete.

Figure 3.1: Admixture: Master Polyhead 8981.

Table 3.14: Admixture properties

Product: Master Polyhead 8981		
Parameter	Specifications (AS PER IS 9103)	Results
Physical state	Reddish brown liquid	Reddish brown liquid
Chemical name of active ingredient	Modified polymeric ether	Modified polymeric ether
Relative density at 25°C	1.08	1.082
pH	Min. 6	6.91
Chloride ion content (%)	Max 0.2	0.0014

3.8 Concrete mix design

To fulfill the mix design and slump criteria different admixtures and various proportions are to be tried for both the grades. Table 3.15 shows the details of requirement criteria for mix design. The concrete mix proportioning using dredged marine sand is not different than the usual mix design of concrete using natural river sand. All the

Table 3.15: Criteria for mix design

Sr No.	Description	Remarks
1	Designed for : R.C.C structure	–
2	Handling Type : Pumpable	–
3	Exposure Condition : Very Severe	–
4	Slump Requirement : 180-200 mm	after 90 minutes
5	Trail Done : 18 (for each grade)	6 different admixtures used

constituents are same for both the cases i.e. concrete using dredged marine sand and natural river sand. The mix design is done based on provisions of IS 10262 (2009).[5]

Table 3.16: Trial Mix Log For M25 Grade Concrete

		w/c	CEMENT	FLY ASH	SAND	10 MM	20 MM	WATER	ADMIXURE	SLUMP MEASURED (mm)
1	28-10-13	0.49	260	87	673	533	740	171	3.817	Initial:140, 60Min:70, 90min:N/A
2	29-10-13	0.49	260	87	673	533	740	171	3.817	Initial:130, 60Min:65, 90min:N/A
3	19-11-13	0.49	260	87	673	533	740	171	3.817	Initial:125, 60Min:65, 90min:N/A
4	25-11-13	0.47	260	87	673	533	740	171	3.817	Initial:135, 60Min:58, 90min:N/A
5	04-12-13	0.49	260	87	673	533	740	171	3.817	Initial:150, 60Min :75, 90min:N/A
6	06-12-13	0.49	260	87	673	533	740	171	3.817	Initial:170, 60Min:100, 90min:N/A
7	08-12-13	0.49	260	87	673	533	740	171	3.817	Initial:180, 60Min:95, 90min:N/A
8	10-12-13	0.49	260	87	673	533	740	171	3.817	Initial:170, 60Min:130, 90min:N/A
9	14-12-13	0.49	269	90	797	470	677	174	2.87	Initial:coll, 30Min:200, 60Min:197, 90min: 185

Table 3.17: Trial Mix Log For M40 Grade Concrete

		w/c	CEMENT	FLY ASH	SAND	10 MM	20 MM	WATER	ADMIXURE	SLUMP MEASURED (mm)
1	28-10-13	0.42	329	110	655	504	696	190	4.201	Initial:140, 60Min:70, 90min:N/A
2	29-10-13	0.43	329	110	655	504	696	190	4.301	Initial:130, 60Min:65, 90min:N/A
3	19-11-13	0.39	329	110	655	504	696	190	5.701	Initial:130, 60Min:65, 90min:N/A
4	25-11-13	0.41	329	110	655	504	696	190	4.932	Initial:135, 60Min:68, 90min:N/A
5	04-12-13	0.43	329	110	655	504	696	190	4.932	Initial:140, 60Min :85, 90min:N/A
6	06-12-13	0.4	329	110	655	504	696	190	4.421	Initial:160, 60Min:100, 90min:N/A
7	08-12-13	0.4	329	110	655	504	696	190	4.31	Initial:180, 60Min:95, 90min:N/A
8	10-12-13	0.4	329	110	655	504	696	190	4.31	Initial:170, 60Min:68, 90min:N/A
9	14-12-13	0.4	324	108	749	464	656	172	3.46	Initial:coll, 30Min:190, 60Min:187, 90min: 175

The w/c ratio is selected 0.48 for M25 grade concrete and 0.4 for M40 grade concrete. For both the concrete grades M40, & M25 the super plasticizer is added for casting of concrete. The amount of 0.8% of total mass of cement was taken as a super plasticizer.

Table 3.16 presents concrete mix proportioning for both concrete grades and for all concrete mixes separately.

Table 3.18: Finalized concrete Mix design

Parameters	M25	M40
Cement(kg/m^3)	269	324
Fly Ash(kg/m^3)	90	108
Fine Aggregate(kg/m^3)	797	749
Coarse Aggregate(kg/m^3)	1147	1120
Water(kg/m^3)	174	172.4
w/c Ratio	0.48	0.4
Superplasticizer(%)	0.8	0.8

3.9 Summary

This chapter includes the data about need to plan mix design, oblige tests for the materials, ingredient's importance in mix design, assessing material properties, results of material properties are discussed in details.

Chapter 4

Experimental Programme

4.1 General

The chapter describes the material properties which have been used in concrete as a fine aggregate i.e. dredged marine sand and natural river sand, coarse aggregates and super plasticizer. Further concrete mix proportion, methods followed for the casting and curing of the concrete specimens are given. Different types of tests with their procedures are explained in detail in this chapter.

4.2 Casting of Concrete

This process plays very vital role with respect to all properties of fresh as well as hardened concrete. First of all weighing and batching process of all ingredients of concrete i.e. cement, fly ash, fine aggregate and coarse aggregate i.e. 10 mm and 20 mm, water and super plasticizer is to be done with higher accuracy before starting the mixing process. Dry mix is to be made in the mixer for 20 to 30 seconds to make the consistent mix by mixing only fine and coarse aggregate first. Cement is added to this mix and after that mixing is started and gradually water is added in the mix. Moulds of the specimens are made ready for pouring the fresh concrete in it by applying proper lubricant as shown in Fig 4.1.

Figure 4.1: Moulds for concrete specimens

The mixing of concrete is performed using Pan mixer as shown in Fig 4.2. The mixing process for all the mixes is same as conventional mixing method. The mixing is continued for 3 to 4 minutes.To check slump requirement for pumpable concrete concrete is kept for 90minutes in the Drum. For the both concrete grade, the chemical admixture i.e. super plasticizer is to be added to the water prior to adding in the concrete mix. The concrete is poured into the moulds of specimens in three layers. Each layer of concrete mix is compacted using 20 mm rod with 25 to 35 manual strokes. The concrete mix is vibrated further until specified condition is attained using table vibrator which is shown in Fig 4.3.

Figure 4.2: Drum Mixture For Mixing of Concrete

Figure 4.3: Table vibrator for compacting concrete mix

After compaction of concrete, the top surface is leveled using trowel and also the sides of mould are struck by using hammer in order to expel air if any present inside the concrete and to make the sides smoothened. The rest period is same as in case of conventional concrete i.e. 24 hour 1/2 hour as per IS 516 (1959).[18] The curing period is decided 7, 28 and 56 days for determining the mechanical properties i.e. compressive strength of plain concrete specimens. For durability aspects 28 days of curing period is done for all specimens i.e. plain and RC specimens. Curing of plain concrete specimens as shown in Fig 4.4.

Figure 4.4: Curing of plain concrete specimens

4.3 Compression Test

Different types of tests are performed to determine mechanical and durability properties of the hardened concrete. Compressive strength of plain concrete is considered. For durability properties such as sulfate resistance test, chloride resistance test, water absorption test, & RCPT test plain concrete specimens are taken.

The mechanical properties of hardened concrete are determined after performing compression test on plain concrete specimens. The compression test is done using 2000 kN capacity hydraulic testing machine. Compressive strength is determined after testing plain concrete cubes of dimension 150 mm X 150 mm X 150 mm as per IS 516 (1959).[6] Fig 4.5 shows plain concrete specimen which is being tested in compression testing machine.

Figure 4.5: Plain concrete cube in compression testing machine

For evaluating the compressive strength of concrete cubes, following Eq 4.2 is used.

$$Compressive\ strength\ of\ concrete\ (N/mm^2) = P/A \tag{4.1}$$

Where P = Failure load in N

A = Area of concrete specimen in mm^2 (150 mm X 150 mm)

4.4 Sulfate resistance test

All the plain concrete specimens are exposed to the sulfate attack for required time duration. After completion of exposure at designated ages, the concrete specimens are taken out of the tank of sulfate solution. The time duration for sulfate exposure, selected for plain concrete specimens is 1 months, 3 months, 6 months and 12 months respectively.

Sodium sulfate (Na_2SO_4) is used to prepare sulfate solution having 5% concentration by total mass of water. [?] The sodium sulfate powder of required quantity is added to water to make the sulfate solution. The sulfate solution is stirred every week and pH value of is measured after interval of 15 days and modification in the pH is done by adding sodium sulfate powder or water in the tank if pH value differs from 1. Fig.4.6 and 4.7 presents concrete specimens for sulfate exposure and sodium sulfate (Na_2SO_4) powder.

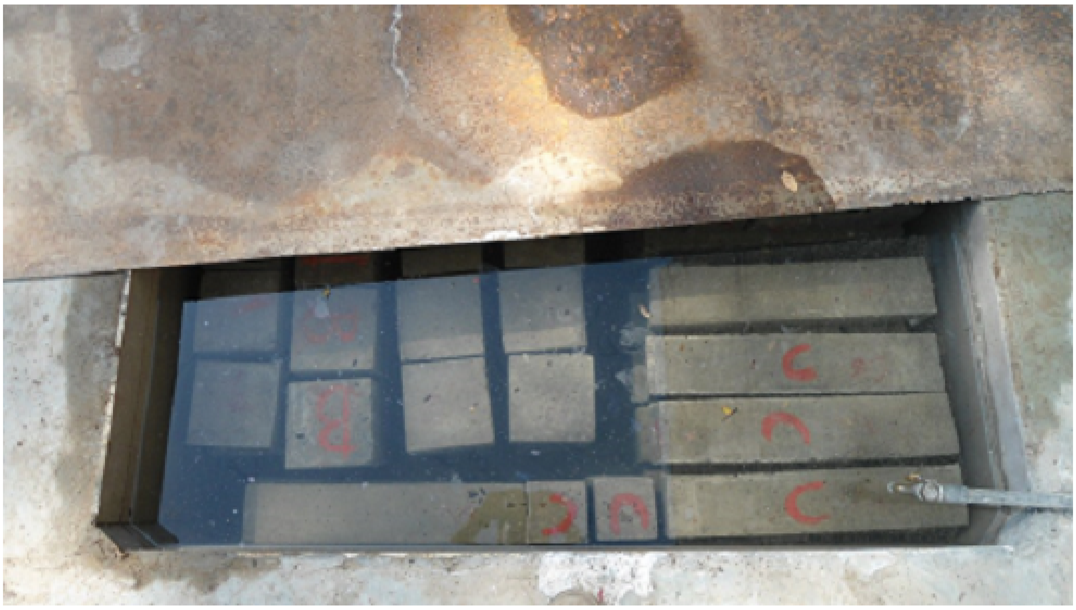

Figure 4.6: Tank of sulfate solution with concrete specimens

Figure 4.7: Sodium sulfate (Na_2SO_4) powder

Table 4.1: Details of sulfate resistance test

Parameters to Study	Unit	Sulfate Solution Concentration	Exposure Ages in Months	Total No. of Cubes
Change in Compressive Strength	MPa	5%	1,3,6,and 12	48
Change in Mass	kg	5%	1,3,6,and 12	
Pulse Velocity by UPV test	m/s	5%	1,3,6,and 12	
* Test specimens of 6 months exposure are to be tested on 17-Aug-2014				
* *Test specimens of 12 months exposure are to be tested on 18-Feb-2015				

The concrete specimens are weighed prior to keep them into the sulfate solution. After removing them out from the tank after completion of exposure, respective specimens are wiped clean and weighed. This is considered as a final weight of concrete specimens in kg. Change in mass of specimens after completion of respective exposure is determined. For evaluating the change in compressive strength of concrete specimens after completion of designated duration in sulfate solution, the specimens are considered saturated surface dry (SSD) condition. Details of sulfate exposure test parameters are given in Table 4.1. The concrete specimen size is 150 mm X 150 mm X 150 mm for this test. They are studied and comparison between all concrete mixes is to be evaluated after completion of exposure in sulfate solution at corresponding time duration.

4.5 Chloride resistance test

All the plain concrete specimens are exposed to the chloride attack for required time duration. After completion of the exposure at designated age, the concrete specimens are taken out of the tank of chloride solution. The time duration for chloride exposure selected for plain concrete specimens is 2 months.

Sodium chloride (NaCl) is used to prepare chloride solution having 3% concentration by total mass of water. The sodium chloride powder of required quantity is added to water to make chloride solution. The solution is stirred every week and pH value is measured after interval of 15 days and modification in the pH is done by adding sodium chloride powder or water in the tank if pH value differs from 1. Fig. 4.8 and 4.10 present tank of chloride solution with concrete specimens and sodium chloride (NaCl). Details of chloride exposure test parameters are given in Table 4.2. The concrete specimen size which was decided is 150 mm X 150 mm X 150 mm for this test. They are studied and comparison between all concrete mixes is to be evaluated after completion of exposure in chloride solution at corresponding time duration.

Figure 4.8: Tank of chloride solution with concrete specimens

Table 4.2: Details of chloride resistance test

Parameters to Study	Unit	Chloride Solution Concentration	Exposure Ages in Months	Total No. of Cubes
Change in Compressive Strength	MPa	3%	1,3,6,and 12	48
Change in Mass	kg	3%	1,3,6,and 12	
Pulse Velocity by UPV test	m/s	3%	1,3,6,and 12	
* Test specimens of 6 months exposure are to be tested on 17-Aug-2014				
* *Test specimens of 12 months exposure are to be tested on 18-Feb-2015				

Figure 4.9: Sodium chloride (NaCl) powder

4.6 Water permeability test

For this test, 150mm×150mm×1500mm cubes are to be cast for both grades. The specimen shall be thoroughly cleaned with a stiff wire brush to remove all laitance. The end faces shall then be sand-blasted or lightly chiselled. The specimen shall be surface-dried and the dimensions measured to the nearest 0.5 mm. It is essential that the seal is ,watertight. This may be checked very conveniently by bolting on the top cover plate, inverting the cell and applying an air pressure of 1 to 2 kg/cm^2 from below.It shall then be centred in the cell, with the lower end resting on the ledge.ith the system completely filled with water, the desired test pressure shall be applied to the water reservoir and the initial reading of the gauge-glass recorded. at the same time a clean collection bottle shall be weighed and placed in position to collect the water percolating through the specimen. The quantity of percolate and the gauge-glass readings shall be recorded at periodic intervals. In the beginning, the rate of water intake is larger than the rate of outflow. As the steady state of flow is approached, the two rates tend to become equal and the outflow reaches a maximum and stabilizes. With further passage of time, both the inflow and outflow generally register a gradual drop. Permeability test shall be continued for about 100 hours after the steady state of flow has been reached and the outflow shall be considered as average of all the outflows measured during this period of 100 hours.test shall preferably be carried out at a temperature of 27^{o}C. The coefficient of permeability shall be caIculated as follows:

$$K = \frac{Q}{4T(H/L)} \tag{4.2}$$

where,

K = coefficient of permeability in cm/set.

Q = quantity of water in milliliters percolating over the entire period of test after the steady state has been reached.

A = area of the specimen face in cm*.

T = time in seconds over which Q is measured.

H/L = ratio of the pressure head to thickness of specimen, both expressed in the same units.

Fig 4.11 shows the concrete specimens which are taken out from water tank and

Figure 4.10: Concrete specimens in water tank for water permeability test

kept for some duration to allow specimens for surface drying.

Figure 4.11: Specimens in Saturated surface dry (SSD) condition

4.7 Rapid Chloride Penetration Test

Corrosion is mainly caused by the ingress of chloride ion into concrete annulling the original passivity present. Rapid chloride permeability test (RCPT) has been developed as a quick test able to measure the rate of transport of chloride ions in concrete. Concrete disc specimens of size 100mm dia and 50mm thick were cast. After 24 hours, the specimen were removed from the mould and subjected to curing for 90 days in chloride permeability.All the specimen were dried free of moisture before testing. the test set up is called rapid chloride penetration test assembly. This is a two-component cell assembly checked for air and watertight.the cathode compartment is filled with 3% Nacl solution and anode compartment is filled with 0.3 NaOH solution. Then the concrete specimens were subjected to RCPT by impressing a 60V from a DC power source between the anode and cathode.Current is monitored up to 6 hours at an interval of 30 minutes. From the current values, the chloride permeability is calculated in terms of coulombs at the end of 6 hours by using the formula.

$$Q = 900(I_0 + 2I_{30} + ... + 2I_{330} + 2I_{360}) \tag{4.3}$$

Where,

Q= Charge passed

I_0= Current immediately after voltage is applied

I_t= Current at t min. after voltage is applied

Table 4.3: Remarks For RCPT Test

Remarks	
Total Charge passed (coulombs)	Chloride Ion Penetration
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very low
<100	Negligible

4.8 Test of Slab Panel

In this test four slab panels were casted by adani at mundra port.All four panel were subjected to alternate drying and wetting condition for 140 days in sea water.The core should then be soaked in water, capped with molten sulphur or any other capping material to make its ends plane, parallel, at right angle and then tested in compression in a surface saturated (moist) condition as per IS 456:2000 or BS 1881: or ASTM C 42. The core samples can also be used for the following:

- Strength and density assessment
- Depth of carbonation of concrete
- Water absorption
- Water permeability (Tested by DIN:1048 Part-5)
- RCPT test (Tested by ASTM C1202)

The Fig 4.13 shows the photograph of slab panel and panel after extraction of cores. and Fig 4.14 shows extracted core specimens.

No Of Core	Grade of Concrete	Test Performed	Casting Date	Testing Date
3	M30 RS & DMS	Compression test	08-09-11	02-06-14
3	M30 RS & DMS	Permeability test	08-09-11	30-05-14
3	M30 RS & DMS	RCPT test	08-09-11	30-05-14
3	M40 RS & DMS	Compression test	23-01-12	02-06-14
3	M40 RS & DMS	Permeability test	23-01-12	30-05-14
3	M40 RS & DMS	RCPT test	23-01-12	30-05-14

Figure 4.12: Summary of core testing

Figure 4.13: slab panel after extraction of core

Figure 4.14: Extracted core specimen

The strength of a test specimen depends on its shape, proportions, and size. The influence of height/diameter (h/d) ratio on the recorded strength of cylinder is an established fact. Strength of cores has to be related to the standard cylinder strengths i.e. for h/d ratio of 2. Thus, core should preferably have this ratio near to 2. For values of h/d between 1 and 2, a correction factor has to be applied. Cores with h/d less than 1 usually yield unreliable results and BS 1881: Pt 4, prescribes a minimum value as 0.95. The same standard specifies the use of 150 mm or 100 mm cores. However, cores as small as 50 mm are also permitted. The general rule adopted for fixing the core size, besides the h/d ratio, is the nominal size of coarse aggregate and the diameter should be not less than 2.5-3 times the maximum size of coarse aggregate.

4.9 Summary

This chapter includes the information about,evaluating material properties, casting of plain concrete cubes, curing and testing procedures are discussed in details.

Chapter 5

Results and Discussion

5.1 General

The chapter contains results of compressive strength after various time duration for all concrete mixes at different ages. The chapter also includes results related to the durability properties such as sulfate resistance, chloride resistance,water absorption test and rapid chloride penetration test for concrete mixes.

5.2 Compressive strength

The evaluation of compressive strength of concrete mixes at 3, 7, 28, and 90 days are presented in Table 5.1, respectively.

Table 5.1: Compressive strength of concrete mixes after various ages

Compressive Strength									
Concrete Grade	Parameter	Strength at 3 days (N/mm2)	Avg. Compressive Strength (N/mm2)	Strength at 7 days (N/mm2)	Avg. Compressive Strength (N/mm2)	Strength at 28 days (N/mm^2)	Avg. Compressive Strength (N/mm2)	Strength at 90 days (N/mm^2)	Avg. Compressive Strength (N/mm2)
M25	RS	11.67	11.30	18.33	18.31	27.78	27.33	29.33	30.37
		10.75		17.57		26.22		30.67	
		11.48		19.04		28.00		31.11	
	DMS	15.36	15.12	21.12	21.24	32.00	31.70	32.33	33.07
		14.41		20.55		30.67		32.89	
		15.57		22.06		32.44		34.00	
M40	RS	18.29	17.11	28.75	27.28	43.56	40.74	47.11	46.00
		16.22		26.50		39.56		46.00	
		16.82		26.60		39.11		44.89	
	DMS	21.10	21.16	29.63	29.73	44.89	44.37	52.00	51.04
		19.83		28.88		43.11		50.00	
		22.56		30.68		45.11		51.11	

Figure 5.1: Failure of Plain Concrete Cube After Compression Test

Increase in compressive strength of all concrete mixes is observed with change in age for both concrete grades i.e. M25 and M40 respectively.

Table 5.2: % Change in Compressive Strength at Intervals of 7 and 28 Days for M25 Grade Concrete

Curing Age in	Mix	7 Days		28 Days	
		M25-RS	M25-DMS	M25-RS	M25-DMS
7	M25-RS	0.00	-	-	-
	M25-DMS	16.00	0.00	-	-
28	M25-RS	49.26	28.68	0.00	-
	M25-DMS	73.13	49.24	15.99	0.00

Table 5.3: % Change in Compressive Strength at Intervals of 28 and 90 Days for M25 Grade Concrete

Curing Age in Days	Mix	28 Days		90 Days	
		M25-RS	M25-DMS	M25-RS	M25-DMS
28	M25-RS	0.00	-	-	-
	M25-DMS	15.99	0.00	-	-
90	M25-RS	11.12	4.20	0.00	-
	M25-DMS	21.00	4.32	8.90	0.00

Table 5.4: % Change in Compressive Strength at Intervals of 7 and 28 Days for M40 Grade Concrete

Curing Age in Days	Mix	7 Days		28 Days	
		M40-RS	M40-DMS	M40-RS	M40-DMS
7	M40-RS	0.00	-	-	-
	M40-DMS	9.00	0.00	-	-
28	M40-RS	49.34	37.03	0.00	-
	M40-DMS	62.64	49.24	8.91	0.00

Table 5.5: % Change in Compressive Strength at Intervals of 28 and 90 Days for M40 Grade Concrete

Curing Age in Days	Mix	28 Days		90 Days	
		M40-RS	M40-DMS	M40-RS	M40-DMS
28	M40-RS	0.00	-	-	-
	M40-DMS	8.91	0.00	-	-
90	M40-RS	12.91	3.67	0.00	-
	M40-DMS	25.28	15.03	10.96	0.00

Table 5.2 shows % change in compressive strength for M25 Grade Concrete after 7, 28, and 90 days.Increase in compressive strength of 16.00% is observed for M25 grade concrete for Dredged Marine Sand respectively as compared to Natural River Sand after 7 days. Increase of 15.99% in compressive strength is observed for M40 grade concrete for Dredged Marine Sand respectively as compared to Natural River Sand after 28 days.

Increase in compressive strength is observed for M25 grade concrete for Natural River Sand with increase in age. Compressive strength gain in M425 grade concrete for Mix M25 DMS is more up to 28 days age as compared to that of Mix M25 RS.

Table 5.3 shows % change in compressive strength for M40 Grade Concrete after 7, 28, and 90 days.Increase in compressive strength of 9.00% is observed for M40 grade concrete for Dredged Marine Sand respectively as compared to Natural River Sand after 7 days. Increase of 8.91% in compressive strength is observed for M40 grade concrete for Dredged Marine Sand respectively as compared to Natural River Sand after 28 days.

Increase in compressive strength is observed for M25 grade concrete for Natural River Sand with increase in age. Compressive strength gain in M40 grade concrete for Mix M40-DMS is more up to 28 days age as compared to that of Mix M40 RS.

The increment observed in compressive strength of concrete using DMS is due to the higher chloride content in DMS as compared to natural river sand. The chloride content present in DMS accelerates the compressive strength during 28 days curing.

5.3 Sulfate exposure

The plain concrete specimens are exposed in the tank with sulfate solution for designated age in terms of months. After completion of the exposure, the concrete specimens are taken out of the tank. The pH value of the sulfate solution is measured which is maintained having value between 8 and 9.

The specimens are taken out of the tank after 1 months,3 months,6 months and 12 months of exposure. The evaluation of change in mass and change in compressive strength is conducted for all concrete mixes. The results of change in compressive strength are presented in Table 5.6. For exploring the quality of specimens UPV test are to be performed for all specimens before and after completion of exposure of 1 months. The results of UPV test are presented in Table 5.9.

Table 5.6: Compressive strength after Sulfate resistance test

Compressive Strength						
Age	28 days normal curing		1 month sulfate exposure		3 month sulfate exposure	
Mix	Strength N/mm2	Avg. Compressive Strength N/mm2	Strength N/mm2	Avg. Compressive Strength N/mm2	Strength N/mm2	Avg. Compressive Strength N/mm2
M25-RS	27.78	27.33	30.22	29.63	24.80	24.87
	26.22		28.89		24.75	
	28.00		29.78		24.90	
M25-DMS	32.00	31.70	33.78	34.81	30.58	30.43
	30.67		36.00		30.32	
	32.44		34.67		30.39	
M40-RS	43.56	40.74	39.56	41.19	35.78	35.85
	39.56		41.33		35.90	
	39.11		42.67		35.88	
M40-DMS	44.89	44.37	44.00	44.89	41.80	41.75
	43.11		43.56		41.78	
	45.11		47.11		41.66	

The compressive strength of concrete specimens for all mixes after 28 days is compared with corresponding compressive strength for the mixes after completion of 1 months sulfate exposure.

Table 5.7: % Change in weight of specimens after 1 and 3 months of sulfate exposure

Mix	Initial Weight	After 1 month exposure	% Change in Wt.	Initial Weight	After 3 month exposure	% Change in Wt.
M25-RS	8.66	8.72	0.54	8.66	8.77	0.85
	8.81	8.85		8.81	8.86	
	8.46	8.50		8.46	8.52	
M25-DMS	8.5	8.52	0.18	8.5	8.54	0.71
	8.4	8.41		8.4	8.53	
	8.55	8.57		8.55	8.56	
M40-RS	8.6	8.66	0.61	8.6	8.66	0.75
	8.45	8.50		8.45	8.52	
	8.4	8.45		8.4	8.46	
M40-DMS	8.7	8.72	0.15	8.7	8.73	0.19
	8.6	8.61		8.6	8.63	
	8.56	8.57		8.56	8.55	

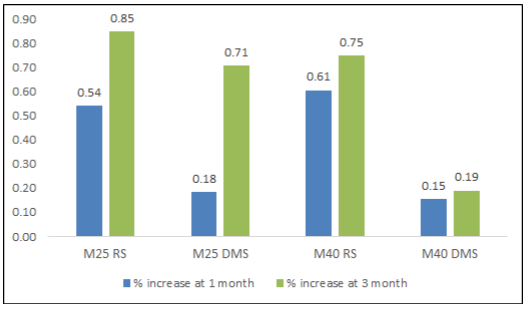

Figure 5.2: % Change in weight of specimens after 1 and 3 months of sulfate exposure for M25 and M40 Grade Concrete

The chemical consequences of sulfate attack on concrete components are the formation of ettringite (calcium aluminate trisulfate 32 hydrate, $CaOAl_2O_33CaSO_432H_2O$) and gypsum (calcium sulfate dihydrate, $CaSO_42H_2O$). The formation of ettringite can result in an increase in solid volume, leading to expansion and cracking. The formation

Table 5.8: Average UPV results for sulfate exposure for all concrete mixes

Sulfate Exposure			
Grade Of Concrete	Mix	Initial Reading (m/s)	Final Reading (m/s)
M25	RS	4150	4148
		4100	3960
		4160	4100
	DMS	4660	4656
		4700	4680
		4730	4700
M40	RS	4830	4800
		4844	4820
		4860	4865
	DMS	4890	4800
		4880	4790
		4900	4890

of gypsum can lead to softening and loss of concrete strength.[14] Both increase in weight and loss in compressive strength of concrete are observed from previous results shown in Table 5.7 and 5.8, respectively.

5.4 Chloride exposure

The plain concrete specimens are exposed in the tank with chloride solution for designated age in terms of months. After completion of the exposure, the concrete specimens are taken out of the tank. The pH value of the chloride solution is measured which is maintained having value between 9 and 9.8.
The specimens are taken out of the tank after 1,3,6 and 12 months of exposure. The evaluation of change in mass and change in compressive strength is conducted for all

concrete mixes. The results of change in compressive strength are presented in Table 5.9. The results of change in mass of the concrete specimens are shown in Table 5.10. The graphical representation related to the same is shown in Fig **??**. For exploring the quality of specimens UPV test was performed for all specimens before and after exposure. The results are shown in Table 5.11.

Table 5.9: Compressive Strength after Chloride Resistance Test

Compressive Strength						
Age	28 days normal curing		1 month Chloride		3 month Chloride	
Mix	Strength N/mm2	Avg. Compressive Strength N/mm2	Strength N/mm2	Avg. Compressive Strength N/mm2	Strength N/mm2	Avg. Compressive Strength- N/mm2
M25-RS	27.78	27.33	26.67	25.93	22.90	22.97
	26.22		25.33		22.89	
	28.00		25.78		23.12	
M25-DMS	32.00	31.70	30.89	31.04	25.38	25.36
	30.67		30.67		25.49	
	32.44		31.56		25.20	
M40-RS	43.56	40.74	38.67	38.37	33.37	33.40
	39.56		38.22		33.44	
	39.11		38.22		33.40	
M40-DMS	44.89	44.37	44.00	42.37	34.16	34.17
	43.11		39.56		34.18	
	45.11		43.56		34.17	

Table 5.10: % Change in Weight of Specimens After 1 and 3 months of Chloride Exposure

Mix	Initial Weight	After 1 month exposure	% Change in Wt.	Initial Weight	After 3 month exposure	% Change in Wt.
M25-RS	8.67	8.68	0.57	8.67	8.68	0.69
	8.79	8.83		8.79	8.85	
	8.65	8.75		8.65	8.76	
M25-DMS	8.66	8.69	0.39	8.66	8.71	0.70
	8.56	8.59		8.56	8.62	
	8.54	8.58		8.54	8.61	
M40-RS	8.36	8.38	0.55	8.36	8.4	0.78
	8.65	8.72		8.65	8.74	
	8.67	8.72		8.67	8.74	
M40-DMS	8.75	8.78	0.15	8.75	8.79	0.31
	8.82	8.83		8.82	8.85	
	8.45	8.45		8.45	8.46	

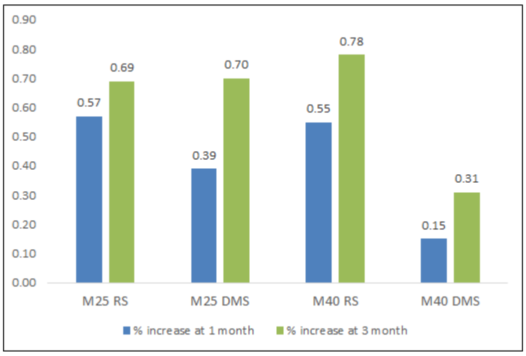

Figure 5.3: % Change in weight of specimens after 1 and 3 months of Chloride exposure for M25 and M40 Grade Concrete

Fig **??** shows that the results for the compressive strength of concrete specimens of M25 grade In that for M25 DMS shows increase in strength of as compared to M25 RS.

For M40 grade concrete made M40 DMS show increment in compressive strength as compared to M40 RS. The percentage of increment in compressive strength is Shows from the 5.2 for M25 grade concrete.The percentage of increment in compressive strength is shows from the 5.3 for M40 grade concrete.

The compressive strength of concrete specimens for all mixes after 28 days is compared with corresponding compressive strength for the mixes after completion of 1 months chloride exposure.

The results of compressive strength of concrete specimens made with DMS indicate that the concrete have less resistance against the chloride attack for the exposure age of 1 months. Therefore further investigation is required to be made with respect to chloride resistance test for concrete made with DMS.

Where concrete structures are placed on reclaimed coastal areas with foundations below saline groundwater level, capillary suction and evaporation may cause supersaturation and crystallization in the concrete above ground. This can result in chemical sulfate attack, physical salt attack, or both. In addition, aggravated corrosion of embedded steel can be induced by the chloride in seawater.This phenomena may be applied in chloride attack, which would increase the weight of concrete after completion of exposure duration.

Table 5.11: UPV results for chloride exposure for all concrete mixes

Chloride Exposure			
Grade Of Concrete	Mix	Initial Reading (m/s)	Final Reading (m/s)
M25	RS	4650	4648
		4657	4652
		4670	4665
	DMS	4950	4940
		4978	4970
		4960	4950
M40	RS	4740	4738
		4690	4675
		4766	4700
	DMS	4870	4866
		4990	4970
		5140	5100

The results of the UPV test for all concrete mixes show that pulse velocity is not that much decreased with higher percentage after completion of 1 months chloride exposure.

5.5 Results of Cores from Slab Panels

The extracted cores were visually examined, prepared and tested in accordance with the requirement/guidelines.The water absorption of the cores has also been tabulated at Table 5.12.

Table 5.12: Water Absorption and Carbonation Result

Core Code	Initial Weight (kg)	Weight after 24 Hrs of water immersion(kg)	%Water absorption	Average % of Water Absoption	Carbonation Effect
M30-RS	7.038	7.046	0.120	0.140	Present
	7.025	7.038	0.180		Present
	7.035	7.043	0.120		Present
M40-RS	6.996	7.007	0.160	0.160	Present
	6.990	7.006	0.230		Present
	7.045	7.051	0.090		Present
M30-DMS	7.035	7.048	0.190	0.220	Present
	6.998	7.013	0.220		Present
	7.048	7.066	0.250		Present
M40-DMS	7.033	7.053	0.280	0.280	Present
	6.032	6.048	0.260		Present
	6.033	6.051	0.300		Present

Figure 5.4: Water Absorption Test

Figure 5.5: Carbonation Effect on Core

Water permeability test and RCPT test is performed by Structwel Designers and Consultants Pvt.Ltd. results of water permeability and RCPT shown in Table 5.13 and 5.14. It can be seen from the observations given in Table 5.13 that use of dredged marine sand produces less permeable concrete mix than that using river sand. RCPT results given in Table 5.14 indicate that concrete with dredged marine sand exhibits better chloride resistance than that with river sand.

Table 5.13: Water Permeability Test Results

Water Permeability Using DIN: 1048 - Part 5						
Sr. No.	ID Mark	Type of Specimen	Specimen Size(mm)	Weight(kg)	Depth of water Penetration(mm)	
					Low	High
1	M40-DMS	Cylinder	ø 120 x 150 mm	4.326	3	6
2	M40-DMS	Cylinder	ø 120 x 150 mm	4.194	4	9
3	M40-DMS	Cylinder	ø 120 x 150 mm	4.286	2	5
4	M40-RS	Cylinder	ø 120 x 150 mm	4.14	6	11
5	M40-RS	Cylinder	ø 120 x 150 mm	3.878	8	13
6	M40-RS	Cylinder	ø 120 x 150 mm	4.122	4	9
7	M30-DMS	Cylinder	ø 120 x 150 mm	4.118	7	16
8	M30-DMS	Cylinder	ø 120 x 150 mm	4.158	5	14
9	M30-DMS	Cylinder	ø 120 x 150 mm	3.984	4	12
10	M30-RS	Cylinder	ø 120 x 150 mm	4.026	5	10
11	M30-RS	Cylinder	ø 120 x 150 mm	4.268	3	8
12	M30-RS	Cylinder	ø 120 x 150 mm	4.112	5	11

Table 5.14: Rapid Chloride Penetration Test Result

Chloride Ion Penetration			
Sr. No.	ID Mark	Time (mm)	Total Charge passed (coulombs)
1	M40-DMS	360	989
2	M40-DMS	360	1256
3	M40-DMS	360	1022
4	M40-RS	360	1641
5	M40-RS	360	1842
6	M40-RS	360	1627
7	M30-DMS	360	1750
8	M30-DMS	360	2051
9	M30-DMS	360	1918
10	M30-RS	360	1254
11	M30-RS	360	1180
12	M30-RS	360	1564

5.6 Summary

This chapter is more important from the experimental point of view. The results observed during the experimental work were presented in this chapter. Results like failure load, strength estimated,& actual strength results were also shown graphically. Failure pattern of different of cube, and other durability test results were also discussed.

Chapter 6

Concluding Remarks and Future Scope of Work

6.1 Summary

The experiment is based on two types of concrete grades i.e. M25 & M40 made with 100% natural river sand, and 100% replacement of natural river sand with dredged marine sand.Total four Mixes are to be used for the study.i.e.,M25 With 100%natural river sand, M25 with 100% dredged marine sand, and M40 With 100%natural river sand, M40 with 100% dredged marine sand.

Basic information related to dredged marine sand i.e. the equipment used for dredging the marine sand, specification of the dredger, practical applications, location of site from where marine sand has been extracted etc. has been described. The aggregates used as a fine aggregate are river sand which is locally available and raw dredged marine sand. The coarse aggregates which are used in concrete manufacturing are of size 10 mm and 20 mm, respectively. Sieve analysis and specific gravity tests are performed for the aggregates. Concrete mix design is done for two concrete grades such as M25 and M40. Casting of plain concrete specimens is done to evaluate compressive strength of all mixes.

compressive strength of concrete cubes are measured after 7 days,1,3,6 and 12 months of moist curing for all mixes.sulfate resistance after exposure of 1,3,6, and 12 months, respectively are carried. chloride resistance after exposure given for the 1 ,3,6, and 12 months, respectively is also executed. Water absorption test, and RCPT tests are performed for all concrete mixes. For Sulfate exposure 5% Na_2SO_4 is used, & for chloride exposure 3% NaCl is used during exposure ages. pH is measured for the accuracy. UPV test is conducted for concrete specimens after 1 month exposur.

6.2 Concluding remarks

Following remarks are made after conducting experimental work in major project.

- It is observed that the compressive strength of concrete increases with the age of concrete irrespective of its grade.
- The rate of increase in compressive strength in case of M25 DMS is more than M25 RS upto 28 days.
- Similarly, the rate of increase in compressive strength in case of M25 DMS is more than M25 RS upto 28 days.
- Generally, chloride content is more in dredged marine sand than river sand. This may be the reason why rate of increase in compressive strength is more in case of dredged marine sand.
- Increase in compressive strength is slightly higher for M40 grade DMS based concrete as compared to that for concrete M40 grade river sand based concrete.
- The study related to sulfate exposure portrayed a good performance of DMS concrete as compared to RS concrete after 3 months of exposure ages.

- The study related to chloride exposure demonstrates inferior performance of DMS concrete as compared to RS concrete which suggest further investigations to be made.
- It is observed from the core testing results that dredged marine sand has more chloride resistance than river sand.
- The concrete mix which is composed of only dredged marine sand exhibit less water permeability than that composed of only river sand.

6.3 Future scope of work

The study may be further extended to include following aspects in the work:

- Further investigations related to chloride resistance od DMS concrete can be done.
- Investigation of other mechanical properties i.e. split tensile strength and flexural strength for concrete mixes using dredged marine sand.
- The behavior of RC beam, column and beam-column joint may be investigated using concrete with dredged marine sand.
- Other durability tests such as permeability test, chloride ion penetration test etc. may be included.
- The durability tests may be extended to RC elements cast using dredged marine sand.
- Concrete made with dredged marine sand as fine aggregate and by using fly ash, silica fume, rice husk ash, slag etc. in addition to OPC.

Appendix A

List of Paper Communicated

- Ravi A. Parmar, Dr. U. V. Dave "Comparative Studies on Compressive strength of concretes using Dredged Marine Sand." Proceedings of the Structural Engineering Convention 2014 (SEC 2014), Department of Civil engineering, IIT Delhi, (Abstract circulated).

- Ravi A. Parmar, Dr. U. V. Dave "Comparative Studies on Compressive strength of concretes using Dredged Marine Sand." Proceedings of the International Conference on Sustainable Civil Infrastructure 2014, American Society of Civil Engineering- Indian section (ASCE Indian section), Department of Civil engineering, IIT Hyderabad, (Abstract circulated).

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