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Contents

IS CODES IN CIVIL ENGINEERING

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The role for standardization in gearing industry to competitive efficiency and quality production. The Indian Standards Institution (ISI) was, therefore, set up in 1947 as a Registered society, under a Government of India resolution.

The Indian Standards Institution gave the nation the standards it needed for nationalization, orderly industrial and commercial growth, quality production and competitive efficiency. However, in 1986 the government recognized the need for strengthening this National Standards Body due to fast changing socio-economic situation and according it a constitutional status. Thus came the Bureau of Indian Standards Act 1986 and on 1 April 1987, newly formed BIS took over staff assets, liabilities and functions of former ISI.

Codes used in India

IS – Indian Standard
IRC – Indian Road Congress
MORTH Specification – Ministry of Road Transport & Highways Specification
IRS – Indian Railway Standard
RDSO Specification – Research Designs and Standards Organization Specification

Different Groups in IS Code for Civil Engineering.

1.Hardware
2.Building Construction Practice
3.Building Lime & Lime Products
4.Cement & Concrete
5.Cement Matrix Products
6.Clay Products
7.Concrete Reinforcement
8.Construction Management
9.Cyclone resistant structure
10.Doors, Windows & Shutters
11.Earthquake Engineering
12.Fire Fighting
13.Fire Safety
14.Flooring, Wall Finishing & Roofing
15.Functional Requirements in Buildings
16.Furniture
17.Gypsum & Gypsum Based Products for Buildings
18.Hill Area Development Engineering
19.Housing – 3 , Methods of Measurement
20.Off Shore Installations
21.Painting, Varnishing & Allied Finishes
22.Planning, Bye Laws & Dimensional Co-ordination
23.Plastic Piping System
24.Ports & Harbors
25.Prefabricated Construction
26.Public Health Engineering
27.Rock Mechanics
28.Safety in Construction
29.Sanitary Appliances & Water Fittings
30.Sieves, Sieving & Other Sizing Methods
31.Soil & Foundation Engineering
32.Special Structures
33.Stones
34.Structural Engineering
35.Structural Safety
36.Structural Sections
37.Timber & Timber Storage
38.Water & Damp Proofing
39.Wood & other Lignocellulosic Products
40.National Building Code
41.Special Publications

Basic Code for Civil Engineering - IS 456: 2000 - Code of practice for plain and reinforced concrete

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OPC 33 -IS 269: 1989
OPC 43 - IS 8112: 1989
PPC- IS 1489: 1991 (Part 1 & 2) OPC 53- IS 12269: 1987
Method of Testing of Cement - 4031 (Part 1 – 15)

Aggregate
Specification for coarse and fine aggregates from natural sources for concrete - IS 383: 1970
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Dimensions for Hot Rolled Steel Beam, Column, Channel and Angle Sections - IS 808: 1989
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Colours for Ready Mixed Paints and Enamels (sixth revision) **- IS 5: 2007**
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Pipes
Specification for fabricated PVC fittings for potable water supplies- **IS 10124: (Part 1-13): 1988**
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Method of test for building limes - IS 6932 (Part 1 – 11) Specification for gypsum plaster
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IS 13311 : Part 2 : 1992
Ultrasonic Pulse Velocity Test
IS: 13311- (Part 1- 1992)

A PREFABRICATED / PANELLED CONSTRUCTION USING GFRG PANEL

Aswathy.PG

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Abstract— Prefabrication is the practice of assembling components of a structure in a factory or other manufacturing site, and transporting complete assemblies or sub-assemblies to the construction site where the structure is to be located. The term is used to distinguish this process from the more conventional construction practice of transporting the basic materials to the construction site where all assembly is carried out. The term prefabrication also applies to the manufacturing of things other than structures at a fixed site. It is frequently used when fabrication of a section of a machine or any movable structure is shifted from the main manufacturing site to another location, and the section is supplied assembled and ready to fit. The conventional method of building a house is to transport bricks, timber, cement, sand, steel and construction aggregate, etc. to the site, and to construct the house on site from these materials. In prefabricated construction, only the foundations are constructed in this way, while sections of walls, floors and roof are prefabricated (assembled) in a factory (possibly with window and door frames included), transported to the site, lifted into place by a crane and bolted together. Common materials used for prefabrication includes aluminium, wood, steel, ferrocement, concrete and glass. prefabricated elements include wall panels, floor /roof panels etc. Recent innovation in panel construction is the introduction of glass fibre reinforced gypsum (GFRG) panel developed by FRBL(FACT –RCF Building products LTD).FRBL GFRG Wall panel is a revolutionary ,low cost, prefabricated , load bearing cellular walling product suitable for use in residential, commercial and industrial building construction. This paper deals with the method of manufacture, properties and construction using glass fibre reinforced gypsum wall panel.

Keywords— Glass rovings, gypcrete, prefabrication ,rapid wall, wall panel.

I. INTRODUCTION

There is a huge growing requirement of building materials in India due to the existing housing shortage of 24.7 million units{ 2007} mainly for the low income groups in urban India. Estimated urban housing shortage in 2012 is 26.53 million, while the housing shortage of rural India in 2012 is 42 million units. Thus total estimated housing shortage for Urban & rural India in 2012 is 68.53 million units. To meet this challenge, India requires innovative, energy efficient building materials for strong and durable housing in fast track method of construction at affordable cost. It is also important that housing and buildings are disaster resistant to protect the lives and properties of people.

All these concerns are involved in sustainable and inclusive development. Rapidwall Panel provides rapid or faster construction and contributes to environmental protection, providing a solution to many of the above issues and concerns. The paper describes the method of construction using Rapidwall panels based on construction manual prepared by IIT Madras to suit Indian situation. FACT & RCF, two fertiliser giants under public sector are together setting up Rapidwall and plaster products manufacturing plant at Ambalamugal

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using Rapidwall technologies of Australia called FACT RCF Building products Ltd. (FRBL). FACT has about 7 million tons of industrial by product gypsum. By setting up Rapidwall & Plaster products plant, they intend to produce 1.4 million sqm or 15 million sq ft panel per year

The threat of climate change caused by the increasing concentration of greenhouse gases in the atmosphere is pushing the whole world into a catastrophic crisis situation with universal concern. The need of the 21st century is for energy efficient and eco-friendly products. The building industry accounts for 40% of CO2 emissions. Building construction causes CO2 emissions as a result of embodied energy consumed in the production of energy intensive building materials and also the recurring energy consumption for cooling and heating of indoor environment.

Rapidwall, also called gypcrete panel is an energy efficient green building material with huge potential for use as load bearing and non load bearing wall panels. Rapidwall is a large load bearing panel with modular cavities suitable for both external and internal walls. It can also be used as intermediary floor slab/roof slab in combination with RCC as a composite material. Since the advent of innovative Rapidwall panel in1990 in Australia, it has been used for buildings ranging from single storey to medium - high rise buildings. Light weighted Rapidwall has high compressive strength, shearing strength, flexural strength and ductility. It has very high level of resistance to fire, heat, water, termites, rot and corrosion. Concrete infill with vertical reinforcement rods enhances its vertical and lateral load capabilities. Rapidwall buildings are resistant to earthquakes , cyclones and fire.

II. MATERIAL

FACT is operating two Phosphoric acid plants viz

- 360 tpd phosphoric acid plant at FACT Cochin Division since 1976
- 100 tpd phosphoric acid plant at FACT Udyogamandal Division since 1966.

With every tonne of phosphoric acid about 4.5 tonne (dry basis) of phosphogypsum is being produced as byproduct. At FACT Cochin division about 1800 tpd and at FACT Udyogamandal division about 300 tpd of gypsum is being generated daily while producing phosphoric acid.

Phosphogypsum is a solid waste and at times it causes disposal problem. At present FACT is having gypsum stock of about 40 to 45 lakh tonnes at its fertilizer manufacturing units viz.FACT Cochin Division and FACT Udyogamandal Division. This phosphogypsum is not having any major use resulting in accumulation of gypsum at both the locations. FACT has done several studies for the effective utilization of gypsum to produce a value added product. However it did not materialize due to techno-economic reasons.

Meanwhile, M/s. Rapid building Systems Pty Ltd. of Australia approached FACT with their innovative technology to manufacture high quality calcined plaster and load bearing wall panels, wall plaster, wall putty and other similar products. RBS have invented innovative gypsum calcining technology known as "Rapid Flow Calciner" to manufacture unique load bearing water resistant glass fiber reinforced wall panels with trade name "Rapidwall". These wall panels are having following advantages over the conventional walls:

1. Eco-friendly and environmentally positive
2. Light Weight
3. Economical and fast construction
4. Water, rot and termite resistance
5. Earthquake, cyclone and fire resistance and
6. Load bearing
7. Speedy Installation
8. Superior Finish
9. Good thermal resistance qualities

Building Materials & Technology Promotion Council under the Ministry of Urban Development & Poverty Alleviation, Govt. of India has issued Performance Appraisal Certificate for Gypcrete Building Panel also called Rapidwall Panel. It is certified that this material has the potential for use in construction of load bearing walls and intermediate as well as roof slabs. Rapid wall panel is a precast, glass fibre reinforced gypsum plaster walling product designed for structural use in general construction.

Panels can be made up to 12m length, 2.85 m height and 120 mm overall thickness. It can be made in smaller sizes also. It can also be cut at construction sites to sizes as required by design and construction. Performance Appraisal Certificate issued for the product by Building Materials and Technology Promotion Council (BMTPC), under Ministry of Urban Development & Poverty Alleviation

building panel is manufactured to the nominal dimensions of 3050mm high by 12020mm long with an overall thickness of 120mm, complete with 48 cavities of 230x94mm. The standard average skin thickness of a panel is 13mm, however the skin thickness can be increased to manufacture up to 150mm thick panel with skin thickness of up to 25mm.

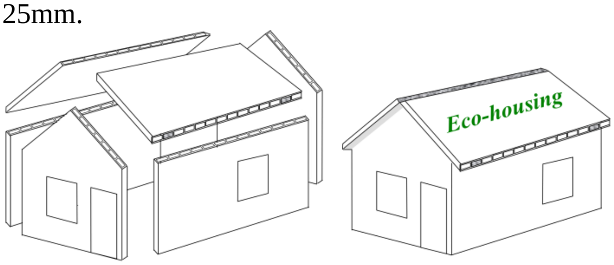


Fig 1: panel building

By cutting into required sizes, 4 for four walls, 2 pieces as roofing panels for sloped roof, a small house can be built by self help within days ……

III.TECHNOLOGY BENEFITS

- ❖ A 12m length x 3m height x 120 millimetre thick Gypsum Wall Panel would weigh around 1.5 tonne compared to 10.5 tonne for the equivalent size of concrete panel.
- ❖ Gypsum Wall Panel is produced generally in a single size as a production-line product and then cut to sizes as per requirement.
- ❖ Depending on the wall layout, when concrete is filled on site a Gypsum Wall panel can support up to 8 storeys thus eliminating the need for columns and floor beams as per BMTPC recommendation.
- ❖ The finish of Gypsum Wall Panel is superior to an equivalent precast-concrete or insitu concrete wall panel.
- ❖ Gypsum Wall Panel can be made from naturally occurring rock gypsum or phospho gypsum which is a byproduct from fertilizer industries.
- ❖ Gypsum Wall Panel has a lower embodied energy than other known comparable walling products [embodied energy is the total energy consumed by the product from the point of extraction of the raw material to the manufacture of the panel, to its transportation to a site and to its final installation on a building project]
- ❖ By the factory production of large single-spanning lightweight wall elements that are easily and speedily erected, the Gypsum Wall Panel system provides a revolutionary and alternative to conventional building methods.

IV.RAW MATERIALS

a) Phospho Gypsum

The basic raw material required is phosphogypsum which is a by-product from FACT's captive phosphoric acid plant of 360 MTPD capacities at FACT Cochin Division. The plant generates around 160 MTPD of phosphogypsum per day on dry basis. The phosphogypsum produced in the plant is acidic in nature (pH is around 4.0). The free moisture content in phosphogypsum produced varies from 14 to 16% by weight typically. However, it can go up to 18% occasionally whenever there are upsets in the filtration process and in other operating parameters. The moisture content in phosphogypsum collected at yard can vary from 15% to 20% depending on the weather conditions.

Fig 2 : phosphogypsum storage

b) Glass roving

Glass Roving are dispersed in the gypsum plaster slurry in preparation of rapidwall panels. This provides strength to the panel. As stated by RBS, good quality glass rovings are available in India at a reasonable rate. The same can also be imported from China. The total requirement shall be 1176 MT per year on full load operation.

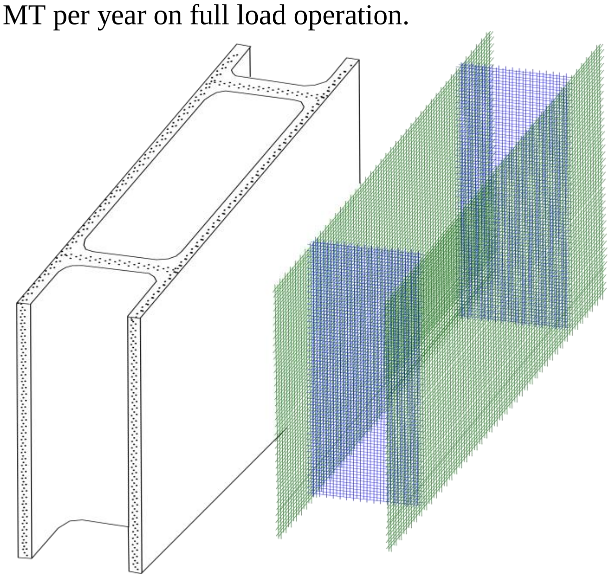


Fig 3:Gypsum wall is reinforced by glass rovings

c) Wax emulsion

Wax emulsion improves the water resistance of the panel. Initially this raw material shall be imported from Australia. Subsequently, efforts shall be made to manufacture the same in India. The total requirement shall be 2614 MT per year on full load operation.

V .WALL PANEL PRODUCT:

Gypcrete Building panel, also called Rapid Building Panel, is a patented product with the registered trade name as “Gypcrete”. Gypcrete is developed in Australia in 1991 and in use there since then as building material in construction of wall panels and floors/roofs. It is also started using in Malaysia and China since 1999-2000

“Gypcrete” is an aggregate made of calcinated gypsum (99.5%), water repellent emulsion, chemicals and reinforced with micro strand of glass rovings (13 microns) by both ways on all four sides-both flanges and webs. This reinforcement provide load bearing capacity & “confinement property” when cavities filled up with concrete. Gypcrete panels can be used as load bearing walls upto two storey buildings. For more than two storeys, cavities of the panel can be filled with concrete and reinforcement.

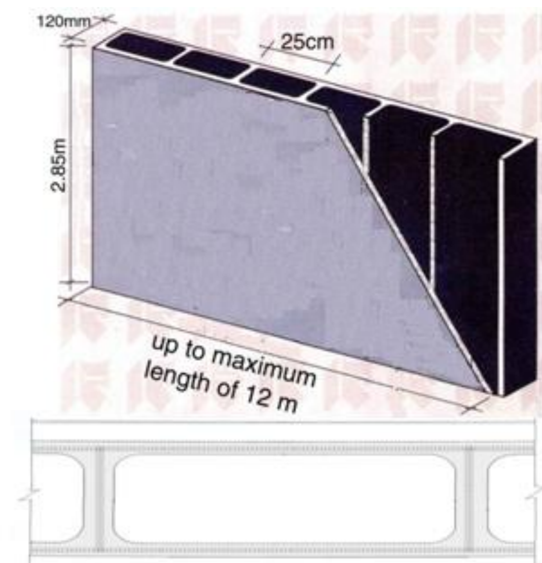


Fig 4 : Cross section of Gypcrete Panel

Gypcrete building panels are lightweight materials and weigh only 40Kg Sq. Mtr. Gypcrete panels have higher flextural strength and ductility compared to bricks/concrete blocks/ hollow blocks making it an efficient and strong building material.

Usage of Gypcrete panels will save cost of foundation, cement, sand; water, shuttering, plastering, electrical concealed wiring, labour and more floor space per building enable cumulative saving about 20-30% in construction. This will also help to save the maintenance cost, energy used in cooling & heating. Construction can be almost instant with superior quality and finish

VI.MANUFACTORING PROCESS

a) Calciner Plant and Calcination Process

The main feed material is industrial by-product waste of phospho gypsum with moisture content of about 10%. Feed material is to be stored in a bulk storage on both open and covered areas and it is not prone to dispersal because of inherent moisture content in phospho gypsum ($CaSO_4$ $2H_2O$). the material is deposited into a fluidized bed of hot calcinating material. The free moisture content is quickly driven off while raising the temperature to required level and removes part of water molecule in the phosphogypsum to make into $CaSO_4$½ H_2O which is suitable for the production of plaster of Paris. There by the material is converted from its di-hydrate form to an essentially hemi-hydrate form. The whole Calcination process works on an integrated control system to allow complete automatic operation.

b) Process Description of Rapid Wall Plant

A set quantity of plaster is fed from Silo 1 via the entoleter into a batch hoper, which is titled under the roof of the building.The Crab assembly is placed in the loading position under the batch hopper. A measured quantity of water is pumped into the mixer bin. Other raw materials, like waterproofing and retarder are loaded into the mixer bin in predetermined and accurately measured quantities. The ingredients are automatically mixed for approximate 20 sec. The plaster is dumped from the batch hopper into the mixer bin. The material is mixed for approximate 1 minute and the slurry is ready to pour 1 for panel manufacturing. The process upto this is fully automatic and operated by a PLC

1st Pour

From the touch screen the operator starts the manufacturing process by driving the crab assembly. The crab drives over the casting table and upon reaching a predetermined position the bin mouth opens and delivers a programmed quantity of gypsum plaster slurry on the casting table. Once this quantity has been delivered, the bin mouth closes automatically. The crab continues to travel past the table. The table operators are now required to use the 1st level screed bar to level the 1st pour.

Laying and rolling 1st layer of glass rovings

With the 1st pour cycle complete the operator now drives the crab back over the casting table. At a predetermined position, the selected glass cutter will automatically begin laying the fiberglass strands along the length of the table until the second preset position has been reached, the glass fiber cutter will stop automatically. The table operators are now required to use the mesh roller effectively submersing the fiberglass into the 1st pour of plaster. The operator continues to drive the crab off the table into the designated crab parking area.

Inserting Plugs

With the 1st pour and 1st glass cycle complete, the operator instigates the insertion of the Plugs. Core puller module is now driven forward to the primary limit. Each module is now raised level and the modules driven forward expanding the plugs. The modules are now driven in reverse to the home limits along with the core table

Laying 2nd layer of glass rovings

Upon completion of inserting the plugs, the crab is again driven back over the table.At the preset starting point the selected glass cutters will begin laying the 2nd layer of fibre glass strands but at a slower speed than the 1st layer.

Tamping the 2nd layer of glass rovings
The staff will now tamp the 2nd layer of glass fiber between each plug, which forms the panel ribs.

2nd Pour

Upon completion of the glass fiber tamping, the crab is now driven back over the casting table for the 2nd pour. At a predetermined position the bin mouth is triggered to open, dispensing the remaining contents of the plaster mix. At preset weight or distance set points the bin mouth will continue to open in stages until reaching the fully open position. Once the mixer is determined as empty the operator instigates the 1st of the mixer wash cycles. The table personnel are now required to level the 2nd plaster pour.

Laying and rolling the 3rd layer of glass rovings

The crab is now driven back over the table for the final time laying the 3rd layer of fiberglass strands. The table staff is now required to screed the plaster and roll the fiberglass strands into the plaster.Once laying the third layer of glass is complete the crab is returned to the loading position for cleaning and reloading of the next panel.

Final screeding

The table staff waits until the plaster is close to the setting time. Just prior to that, they screed the panel for the final time to obtain a clean and flat finish on the B side of the panel.

Removing the panel

Approximately 20 minutes after the final screeding, the casting table is tilted and the finished panel is removed by a fork lift equipped with a specially designed lifting frame

Rapid wall Dryer

Finished Rapidwall panels are transported from Rapidwall plant to the drying plant. The panel is transferred from the Acroba frame to the Drying plant frame. The drying plant consists of 2 drying room chambers which can hold 3 Rapidwall panels each.Once 3 panels are loaded, the panels are pushed into the drying chamber and the door is closed.The operator starts the automatic drying cycle. The panels will be dry in approximate 2 hours. Panels can be transported to the Rapidwall saw for cutting and dispatch.

Rapid wall Panel Cutting

The Rapidwall panels will be transported direct from the drying room or from the drying racks into the tilt table of the saw.The panels are now lowered into a horizontal position and automatically moved lengthwise under the cutting heads of the saw.

The saw consists of 12 cutting blades which are all computer controlled.The panel size is entered into the PLC on a touch screen, including window and door – openings.The cutting saw is fully enclosed and equipped with a dust extraction system, which ensures a dust free operation.

VII.PHYSICAL AND MATERIAL PROPERTIES

Rapidwall panel is world's largest load bearing lightweight panels. The panels are manufactured with size 12 m length, 3m height and 124 mm thickness. Each panel has 48 modular cavities of 230 mm x 94 mm x 3m dimension. The weight of one panel is 1440 kg or 40 kg/sqm. The density is 1.14g/cm3, being only 10-12% of the weight of comparable concrete /brick masonry. The physical and material properties of panels are as follows:

Table 1: physical and material properties of panels

Weight- light weight	40 Kg/ sqm
Axial load capacity	160 kN/m{ 16 tons/ m}
Compressive strength	73.2 Kg/cm2
Unit Shear strength	50.90 kN/m
Flexural strength	21.25 kg/cm_2
Tensile Strength	35 KN/ m
Ductility	4
Fire resistance	4 hr rating withstood 700-1000_0 C
Thermal Resistance R	0.36 K/W
Thermal conductivity	0.617
Elastic Modulus	3000-6000Mpa
Water absorption	< 5%

VIII. CONSTRUCTION METHODOLOGIES

a) Foundation

For Rapidwall buildings/ Housing a conventional foundation like spread footing, RCC column footing, raft or pile foundation is used as per the soil condition and load factors. All around the building RCC plinth beam is provided at basement plinth level. For erection of panel as wall, 12 mm dia vertical reinforcement of 0.75m long of which 0.45m protrudes up and remaining portion with 0.15m angle is placed into the RCC plinth beams before casting. Start up rods are at 1m centre to centre

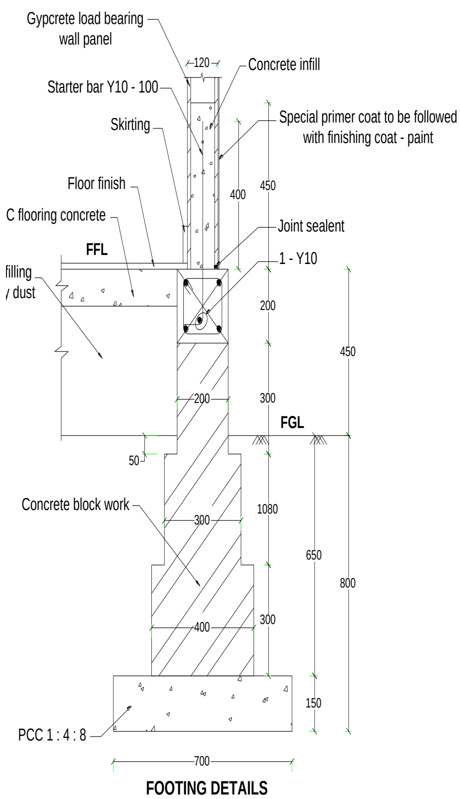


Fig 5: footing details

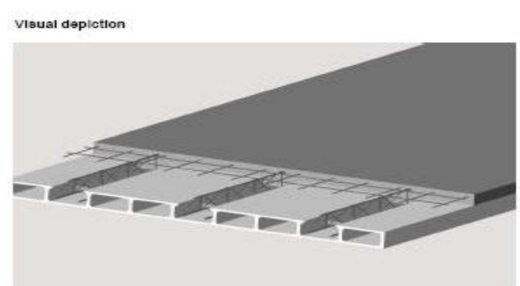
b) wall construction

All the panels are erected as per the building plan by following the notation. Each panel is erected level and plumb and will be supported by lateral props to keep the panel in level, plumb and secure in position. Once wall panels erected, door and window frames are fixed in position using conventional clamps with concrete infill of cavities on either side. Embedded RCC lintels are to be provided wherever required by cutting open external flange. Reinforcement for lintels and RCC sunshades can be provided with required shuttering and support

After inserting vertical reinforcement rods as per the structural design and clamps for wall corners are in place to keep the wall panels in perfect position, concrete of 12mm size aggregate will be poured from top into the cavities using a small hose to go down at least 1.5 to 2 m into the cavities for directly pumping the concrete from ready mix concrete truck. For small building construction, concrete can be poured manually using a funnel. Filling the panels with concrete is to be done in three layers of 1m height with an interval of 1 hr between each layer

c) Roofing

Rapidwall Panel can also be used for intermediary floor slab / roof slab in combination with embedded RCC micro-beams and RCC screed concrete.Each roof panel is placed over the wall in such a way that there will be at least a gap of 40 mm. This is to enable vertical rods to be placed continuously from floor to floor and provide monolithic RCC frame within Rapidwall. Wherever embedded micro-beams are there, top flanges of roof panel are cut leaving at least 25mm.Reinforcement for micro-beams is placed and weld mesh as reinforcement is placed. Concrete is poured for miro-beams and RCC slab. This results in the embedded RCC micro beams and 50 mm thickness screed concrete becoming a series of “T” beams



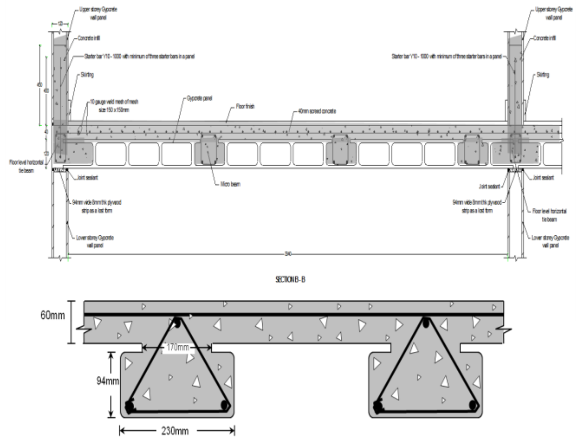


Fig 6: Reinforcement details of roof slab

IX. COMPARISON BETWEEN RAPID WALL AND CONVENTIONAL BUILDING

Table 2: Comparing rapid wall and conventional building

materials	Rapid wall building	Conventional building	Saving in %
Cement	16 tones	32.55 tones	50.8
Steel	1800 kg	2779 kg	35.2
River sand	20 cum	83.37 cum	76
Granite metal	38 cum	52.46 cum	27.56
Brick		57200	
GFRG panel	500 sqm		
Water	50000 ltr	200000 ltr	75
Built area	143 sqm	154.45 sqm	8
labour	389 man days	1200 man days	67.59
Construction time	21 days	120 days	82
Weight of structure	170 tones	490 tones	65
Construction cost	13.25 lakhs	18.27 lakhs	27.47
Embodied energy in KWh	82921	215400	61.5

X. CONCLUSION

Rapidwall Panel provides a new method of building construction in fast track,fully utilising the benefits of prefabricated, light weight large panels with modular cavities and time tested, conventional cast-in-situ constructional use of concrete and steel reinforcement. By this process, man power, cost and time of construction is reduced. The use of scarce natural resources like river sand, water and agricultural land is significantly reduced. Rapidwall panels have reduced embodied energy and require less energy for thermo-regulation of interiors.

Rapidwall buildings thereby reduce burdening of the environment and help to reduce global warming. Rapidwall uses also protect the lives and properties of people as these buildings will be resistant to natural disasters like earthquakes, cyclone, fire etc. This will also contribute to achieve the goal of much needed social inclusive development due to its various benefits and advantages with affordability for low income segments also. Fast delivery of mass dwelling/ housing is very critical for reducing huge urban housing shortage in India. Rapidwall panels will help to achieve the above multiple goals.

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Quantitative Estimation of Morphological Changes in the Cochin Estuarine System: A GIS and Remote Sensing Approach

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***Abstract*— Cochin Estuarine System (CES) is a unique complex system along the Indian coastline with a widespread area at the upstream. Increased human activities such as industrialization, coupled with over-population have become major environmental issues in recent years. Quantification of geomorphological changes that occurred over the decades was identified using Landsat Imageries of different years in comparison with Survey of India toposheet as baseline data. Shorelines from multiple years were manually traced from toposheet and Landsat imageries, using ArcGIS Version 10.0 software. Quantitative comparison of inner island segments showed significant changes in island widths through time. The shoreline change rate has been estimated using statistical linear regression, end point rate and net shoreline movement method and cross-validated with regression coefficient (R^2) method. This study has given good insight into Cochin coastal zone changes during last 4 decades. These results can be used to quantify the extent and nature of the development change and to understand the surrounding environment, which in turn may help the planning agencies to develop sound and sustainable coastal zone management practices**.

***Keywords*— Cochin Estuarine System (CES), ArcGIS software, Geomorphological changes, shoreline change rate, regression coefficient**

I. INTRODUCTION

Estuaries are commonly described as semi-enclosed bodies of water, situated at the interface between land and ocean, where seawater is measurably diluted by the inflow of fresh water. They are very dynamic systems in terms of hydraulic, morphological and ecological functioning. The interaction between various natural processes and human activities in an estuary is a very important factor. The natural factors which influence the changes in the estuaries largely depend on its geology and geomorphology, the nature of tidal waves impacting the coastline, changes in sea-level, climatologic conditions and sediment transport by long shore currents. Also the human activities that impact coastlines include dredging, construction of breakwater infrastructure, port construction, removal of backshore vegetation, land reclamation, construction of barrages and coastal control works etc.

Since ages estuaries have been densely populated areas. Of the 32 largest cities in the world, 22 of them are located along estuaries. Many estuaries around the world are at the same time economically important links between land and sea, providing access to harbours and inland waterways, and valuable natural environments, providing shelter, feeding and breeding grounds and nurseries to a wide variety of species. In the past, these functions could mostly be combined without much trouble, but now that man is interfering with these systems at an ever larger scale and is putting higher demands on navigability for larger ships, many estuarine ecosystems are stressed to the extreme.

Thus coastal zone monitoring is an important task in national development and environmental protection. The extraction of coastlines should be regarded a fundamental research of necessity. Nowadays the coastal zone is receiving an increasing attention because of the pressure of increasing population and industrial developments. Protection of natural resources, the loss of habitats, severe coastal erosion, sedimentation in ports and harbors and municipal and industrial pollution are major concerns for coastal zone managers. Coastal zone and its environmental management require the information about coastlines and their changes.

The coastline or shoreline can be geographically defined as a linear intersection of coastal land and the surface of a water body. The coastline changes its shape and position continuously due to dynamic environmental conditions. Shoreline is one of the most rapidly changing landforms of the coastal zone. Geomorphic processes such as erosion, deposition, sedimentation, periodic storms, flooding and sea level changes are continuously modifying the shoreline. The accurate mapping of shoreline is therefore very important for planning conservation measures such as protection of human life, property and natural environment. The rate of shoreline changes is one of the common measurements used by coastal scientists, engineers and land planners to indicate the dynamics and the hazards of the coast.

Coastline change detection can be done by comparing the topographic maps or aerial photographs of different periods. Moreover, satellite imagery has been used to describe coastal changes, and this method has been proved to be a unique tool for environmental research because the mapping of the coastline is accurate and provides with multiple and update information. Remote sensing techniques integrated with the Geographic Information System (GIS) have been used for many studies. The integrated method has been used in the coastal zone change detection due to repetitive and synoptic coverage, high resolution, multi-spectral data base and its cost effectiveness. Hence, in order to study the coastal processes in the study area, the shoreline change, and coastal geomorphology were analyzed using Remote Sensing and GIS tools.

II. STUDY AREA

Cochin ($9^0$58' N, $76^0$14' E) is situated in the state of Kerala on the SW coast of India. The Cochin Estuarine System (Fig. 1), approximately 320 km^2 in area, consisting of Vembanad lake and the surrounding islands, with six rivers (Periyar, Pampa, Achankovil, Manimala, Meenachil and Muvattupuzha) flowing into the estuary. The Cochin Estuary is the second largest wetland ecosystem in India, sustaining rich bio-resources.

The Cochin Estuary constitutes a complex estuarine system, characterized by an oxbow shape with its long axes running parallel to the coast and numerous islands. The estuary is connected to the Arabian Sea at two locations, Cochin (Lat.9°58'N) and Azhikode (Lat.10°10'N) and is divisible into two parts: the southern arm extending from Cochin to the south and the northern arm extending from Cochin to Azhikode. The Cochin inlet is about 450 m wide, whereas Azhikode inlet is relatively narrow. During December to April, a salinity barrier at Thanneermukkom virtually cuts off the tidal propagation further south and modifies the circulation in the remaining part of the estuary. The important features of the southwest monsoon that vary from year to year are the onset date, quantity of rainfall and the duration of the season, which eventually result in the variability of estuarine characteristics, including water level and flow.

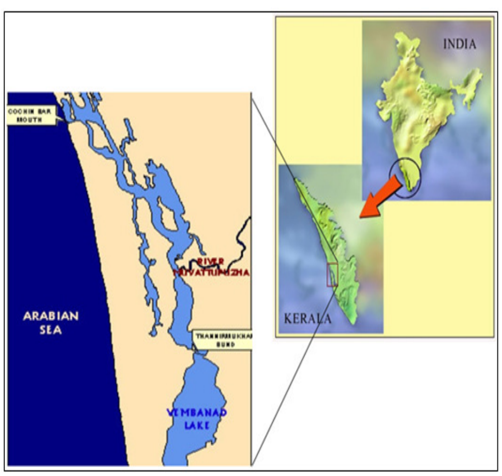

Fig.1. Location Map of Study Area

The tides (as well as larger ships) enter and exit the Cochin Estuary through a perennially open narrow inlet, the cross sectional area of which is approximately 4234 m^2. The major sources of sediments to the Cochin harbour are mainly the two large rivers Muvattupuzha and Periyar (and the four other rivers, to a lesser extent). To counteract sedimentation in the Cochin harbour, dredging of the port area is carried out throughout the year. The Cochin port trust maintained three dredged channels: Approach channel (10km), Ernakulam Channel (5km), and Mattanchery channel (3km). The important channels inside the estuary are the Ernakulam and Mattanchery channels, which lie to the east and west of the Wiilingdon Island (Fig. 2).

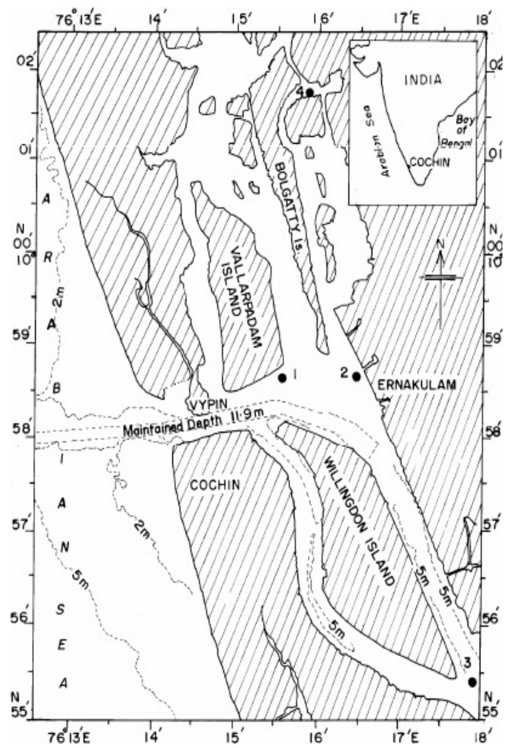

Fig. 2 Dredged channels in the study area

Major modifications that had taken place in the morphology and ecology of the system in the course of its history can be seen as combinations of natural processes and human interferences, of which the latter has lead to serious alterations to the system. The project to develop Cochin into a major portion the west coast of India commenced in 1920 and was completed in 1936, for which an area of about 365 ha was reclaimed. Thereafter, there were no major reclamations until the 1970s, when the fishery harbor with an area of 11 ha was reclaimed. This was followed by an integrated island development project, in which 142 ha was reclaimed. An equal area of the estuary was reclaimed for the southern extension of the port. Since then, the estuary has been subjected to substantial anthropogenic modifications for various projects for urban development and town planning, such as construction of foreshore roads, bridges, a shipyard, additional berthing facilities, a container cargo terminal, tourist sports development, and island development. Recognizing its socioeconomic importance, it has been included in the Ramsar site of the world's vulnerable wetlands to be protected (Wetlands, 2002).

The backwater system located between $09^0$30' N, $76^0$15' E and$10^0$10' N, $76^0$25' E is generally known as the Cochin backwaters. Constant mixing with the seawater through the tidal exchange gives the backwaters the characteristics of a typical estuary. The estuary depicts an interesting physiography dominated by several inner estuary islands. The port facilities are located at the mouth of the Cochin estuary. A highlight of the port is that it provides placid water spread, which retains its calmness even during the roughest weather, because the vast and extremely tranquil harbour basin is protected by the peninsular headlands on each side (Kumar, 2013).

III. OBJECTIVES

The objectives of the present study are to assess the geomorphologic changes that occurred over the decades in the in the Cochin Estuarine System using remote sensing and GIS techniques.

The specific objectives of the study can be stated as:

- To prepare geomorphologic map of the study area for different periods using toposheet and satellite images.
- To quantify the changes in the inner estuary island segments from the geomorphologic map.
- To estimate the rate of change in the shoreline positions using Digital Shoreline Analysis System (DSAS), an Arc GIS extension tool.

IV. DATA SOURCES AND MATERIALS

Multi-resolution satellite data over the study area, such as Landsat MSS, TM, ETM+ and Landsat 8 of different dates have been acquired, as the same resolution data is not available over the chosen period (1973-2014). The archived Landsat images are freely available to the users so these are used. The ortho-rectified Landsat data were downloaded from the USGS global visualization viewer. The area is covered by the Survey of India (SOI) Toposheet No. 58B4, 58B8, 58C1C5, 58C6 at 1:50, 000 scales which were collected from Kerala Forest Research Institute, Trissur. Landsat data is typically used for coastal zones because of the multi-spectral and multi-temporal capabilities of the data. However, only multi-temporal data have been utilized that allow us to keep track of the various changes in characteristics of the coastal zone. The satellite data sensor's characteristics are summarized in Table 1.

TABLE 1 SATELLITE DATA SENSOR'S CHARACTERISTICS

Sensor	**Characteristics**		**Path and Row**	**Date of Acquisition**
	Spatial Resolution (m)	***Number of Bands***		
Landsat-1 MSS	60	4	155/53	February 10, 1973
Landsat-5 TM	30	7	144/53	January 24, 1990
Landsat-7 ETM+	30	8	144/53	October 26, 2000
Landsat-7 ETM+	30	8	144/53	February 10, 2005
Landsat 8 OLI-TIRS	30	11	144/53	February 11, 2014

V. METHODOLOGY

The morphological change detection in Cochin estuary was studied by comparing satellite imageries of 1990 (Landsat-5 TM), 2000 (Landsat-7 ETM+) and 2014 (Landsat 8 OLI-TIRS) with the survey of India toposheet of 1970. The Survey of India toposheet (58C01, 58C06) was mosaicked for delineating the study area using image processing software ERDAS 9.2. It was then reprojected to Universal Transverse Mercator zone 43 north projection systems. For the satellite images, different band combinations were tried for better land-water interpretation and selected the suitable one. The layer stack option in Erdas 9.2 was used for this purpose. Geometric corrections were made to correct the inaccuracy between the location coordinates of the picture elements in the image data, and the actual location coordinates on the ground. The ground control points for geocoding satellite imageries were found with the help of georeferenced toposheet, and these points were uniformly distributed across the study area. A total of at least 25 prominent ground control points (GCP) was examined and matched in all images with the help of toposheet. The root-mean-square error was less than 0.5 pixels for each image. After georeferencing, the nearest-neighbour interpolation method was employed for rectifying and resampling the images into a geographic coordinate system and then reprojected to Universal Transverse Mercator zone 43 north projection systems. The study area was extracted using Erdas Imagine software. The land–water system for toposheet was digitized with the help of ArcGIS v.10 software, and onscreen digitization of the same was done for the satellite imageries to get an idea of the present position of the system. The vector representations of the Cochin estuary for 1970, 1990, 2000 and 2014 were overlaid by using the union option. The area under degradation and accretion was demarcated and represented based on changes as shape files. The area was calculated using calculate geometry option in the attribute table. The digitized image for the year 2014 with major islands was shown in Fig. 3.

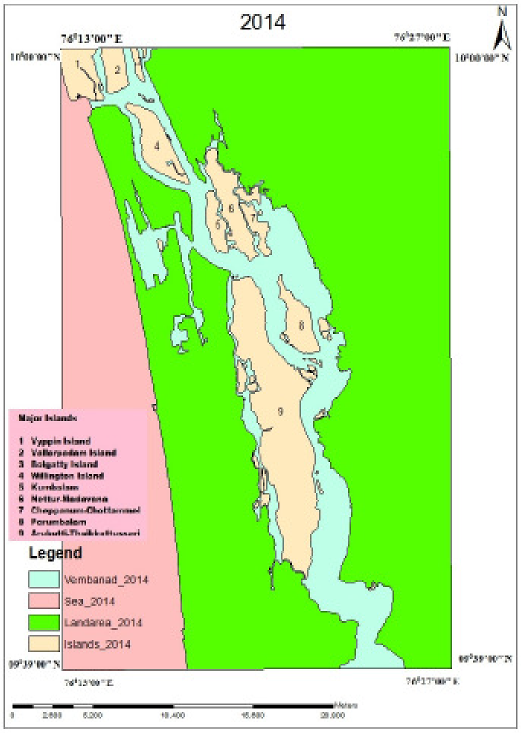

Fig. 3 Digitized image of the study area (*2014*)

To carry out shoreline changes study a Digital Shoreline Analysis System (DSAS), an extension of ARC GIS, was employed. Fig. 4 shows a typical DSAS workflow. The procedure involves the selection of a baseline in the general direction of a shoreline, establishing transects perpendicular to the base line and then finally calculating the distance between the shorelines along various transects. The rate of change in shoreline positions has been estimated using Linear Regression Rate (LRR), End Point Rate (EPR) and Net Shoreline Movement (NSM) method and cross-validated with regression coefficient (R^2) method. The end point rate calculations are done by dividing the distance of shoreline movement by the time gap between the oldest and youngest shoreline in the data set. The major advantage of this method is ease of computation and calculations can be done on minimum two shorelines only. The EPR method is only good for short term shoreline change analysis as it only considers latest and the oldest shoreline position and suppresses all in other in long term analysis. Uses of LRR eliminate this difficulty. Here the shoreline shift is calculated by fitting a least square regression line to all shoreline points for a particular transects. The net shoreline movement (NSM) reports distance not rate. It reports the distance between the oldest and youngest shorelines for each transect. The calculations were done using Digital Shoreline Analysis System (DSAS) tool. The inputs required for this tool are shoreline in the vector format, date of each shoreline, and transect distance.

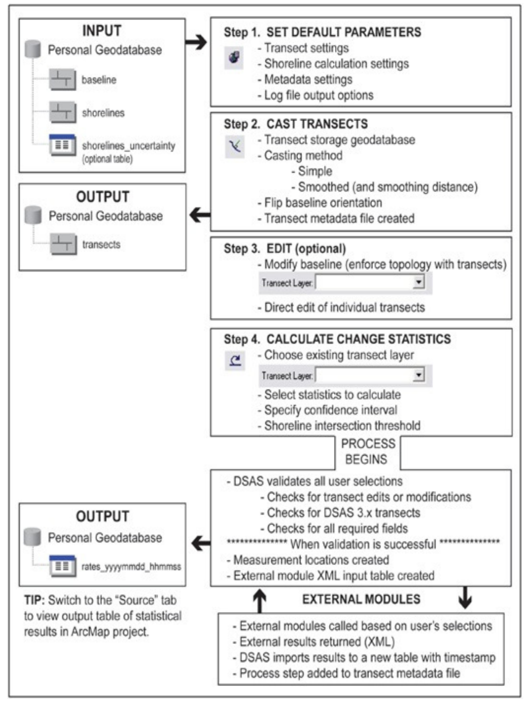

Fig. 4 DSAS workflow

Thus shoreline changes in the study area were analyzed in ESRI ArcGIS v 10.0 Software with five Landsat images of the years 1973, 1990, 2000, 2005, and 2014 and toposheet for the year 1970. The continuous shoreline positions during different years (1970, 1973, 1990, 2000, 2005 and 2014) were digitized through shape files with the utmost accuracy. The created shorelines were then merged for calculation purpose. It was done according to the period and method of calculation. For example, Linear Regression Rate (LRR) method needs all shoreline positions for the calculation. So, all the six shorelines were merged to a single feature class for LRR calculation. But for End Point Rate (EPR) method and Net Shoreline Movement (NSM) method accepts only two shoreline positions (latest and earlier) for the calculation. So they are merged for the periods 1970-1973, 1973-1990, 1990-2000, 2000-2005, 2005-2014, and 1970-2014. DSAS uses a measurement baseline method to calculate the rate-of-change statistics for a time series of shorelines. The baseline is the starting point for all transects and is therefore one of the most important components of the shoreline change analysis process. In this study, three baseline segments were created as

per the shoreline conditions since the shoreline is not continuous. It was then merged to form a single feature class.
In this study, the transect spacing was given as 300 m and the transect length was set as 2300 m. Different transects sets were generated for each calculation methods. 141 transect with a spacing of 300m each are drawn perpendicular to this general orientation and calculations are done along these. After creating transect sets change statistics were calculated using DSAS tool

VII. RESULT AND DISCUSSIONS

A. Geospatial Analysis of Land-Water Interface

The land-water interface change was determined by overlaying the previously prepared digitized images. Fig. 5 shows the changes that occurred in the land–water interface in the estuary during 1970, 1990, 2000, and 2014.

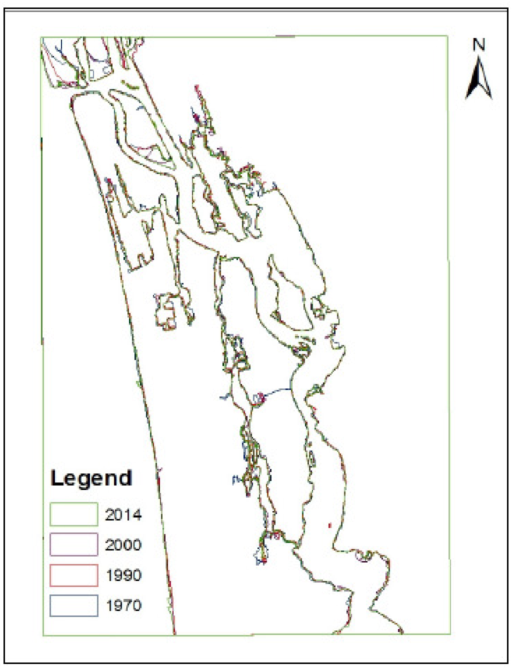

Fig. 5 Changes in land-water interface during 1970-2014

From the figure 5, it is clear that during the period of 1970–2014, major shoreline changes had taken place in the northern segments of the estuary mouth, whereas the southern zones exhibited only minor variations in the widths. The accretion in the major barrier island of Vypin Island resulted in the shifting of the shoreline in the seaward direction. During 2000–2014, the shoreline position in Vypin Island moved slightly to the east, resulting in erosion of land area. In 2004, tsunami waves hit these shores, which might have resulted in this change. But the overall changes from 1970-2014 resulted in accretion in the estuary mouth. Fig. 6 depicts the major shoreline changes observed in the estuary inlet and mouth. The bar mouth of the estuary was found to have protruded by 1.75 km towards the sea, resulting in a drastic reduction in the width of the estuary mouth. The shoreline receded by about 954 m at Elangunnapuzha (Malippuram) in Vypin. A recession of about 1.36 km occurred at the southernmost tip of the zone. The study reveals the major variation of the geomorphologic pattern in the mouth regions of the estuary.

Fig. 6 Changes in the estuarine mouth

B. Changes in the Inner Estuary Islands

From the digitized images of each year, the area is noted for the major islands. Details of the quantitative comparison of morphological changes of the inner island segments are given in Table 2.

TABLE 2 AERIAL EXTENT OF MAJOR ISLANDS IN THE COCHIN ESTUARY

Major Islands	**1970 (km^2)**	**1990 (km^2)**	**2000 (km^2)**	**2014 (km^2)**
Vypin Island	3.3276	5.2987	6.8036	6.9654
Vallarpadam	1.7628	3.5282	3.4490	3.7373
Bolgatty Island	0.4971	0.4605	0.5503	0.8114
Willington Island	6.4664	6.4372	7.4745	7.9326
Kumbalam	3.2131	3.2308	3.2907	3.4092
Nettur–Madavana	8.1364	7.9896	8.5537	8.3649
Cheppanum–Chottammel	2.3765	2.4640	2.5317	2.5273
Perubalam	5.7568	5.7846	5.9679	6.0282
Arukutti–Thaikkatusseri	45.3230	46.6353	47.2753	47.1331

Accretion of 10.05 km^2 occurred during 1970–2014. During the 44-year period (1970–2014), the northern segments of the study area experienced major changes due to accretion and erosion of the land–water system in the estuary. The islands toward the northern part of the study area made major contributions to the morphological changes in the land–water system. Vypin Island accreted by about 3.64 km^2 offshore during the period 1970–2014. All of these have contributed to the narrowing of the estuary mouth, which is protruding toward the sea.

C. Shoreline Change Rate Analysis

The three analytical methods used to calculate shoreline change rate are Linear Regression Rate (LRR), End Point Rate (EPR) and Net Shoreline Movement (NSM). The transects created for LRR method in the estuary mouth is shown in Fig. 7. The best fit line created for the transect id 37 of baseline segment 1 is shown in Fig. 8 and for transect id 135 of baseline segment 3 is shown in Fig. 9. From these figures, it is clear that the transect id 37 having R^2 value nearly zero depicts erosion and accretion is happening in a balancing way for that particular position. But for the transect 135 (Vypin Island area) shows a linear pattern with R^2 value 0.95 (accretion). The rate calculation results for EPR and NSM methods are listed in Table 3 with negative values representing recession and positive values indicating accretion.

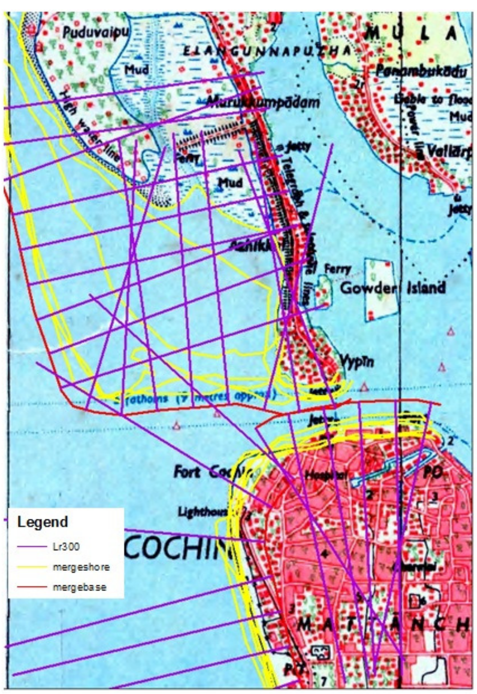

Fig. 7 Transects created for the estuary mouth

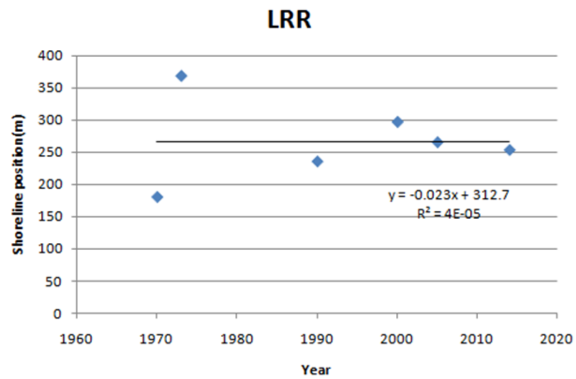

Fig. 8 Transect id 37: Baseline segment 1

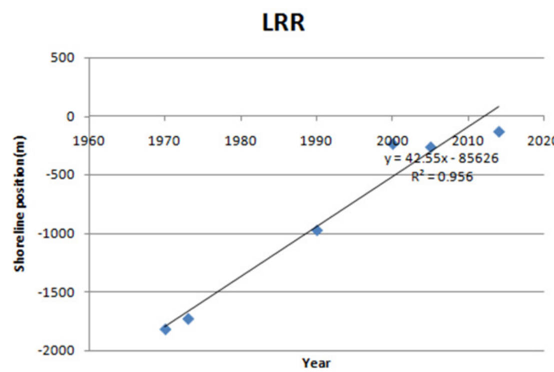

Fig. 9 Transect id 135: Baseline segment 3

TABLE 3 SHORELINE CHANGE RESULTS FOR EPR AND NSM METHODS

	Year	1970-1990	1990-2000	2000-2014	1970-2014
EPR (m/y)	Mean	3.61	6.68	0.57	3.40
	S.D	17.6	14.33	5.85	10.51
	Max.	71.51	72.63	22.03	44.39
	Min.	-9.08	-20.76	-44.3	-2.34
	Year	**1970-1990**	**1990-2000**	**2000-2014**	**1970-2014**
NSM (m)	Mean	72.36	71.81	7.54	149.99
	S.D	353.06	154.11	77.77	463.63
	Max.	1434.7	781.21	292.83	1958.17
	Min.	-182.21	-223.24	-588.87	-103.21

The rate calculation results of LRR method are listed in Table 4. The distribution of R^2 values is shown in Fig. 10.

TABLE 4 SHORELINE CHANGE RESULTS FOR LRR METHOD

	Year	1970-2014
LRR (m/y)	Mean	2.39
	S.D	11.27
	Max.	47.57
	Min.	-2.82

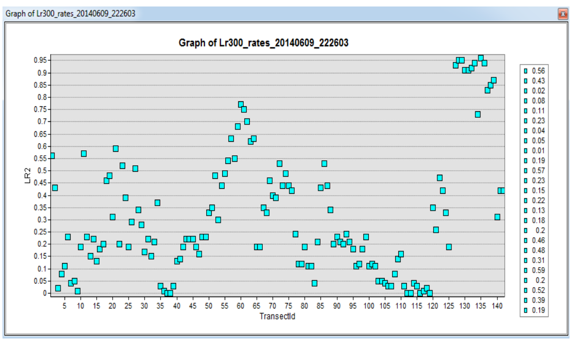

Fig. 10 Distribution of R^2 values obtained from LRR method

EPR for the entire shoreline shows that 96.5%, 14%, 82% 54% and 57% transects, records the accretion during the time span of 1970-1973,1973-1990,1990-2000, 2000-2005 and 2005-2014 respectively. Whereas the rest of the transect lines experience erosion during the same time span. In LRR method, the shoreline shift rate can be predicted by fitting a least square regression line with the observed shoreline position along a transect line. The distribution of R^2 value for all the transect lines throughout the shoreline shows some distinctive distribution pattern. Transect 126 to 139 have the R^2 value > 0.85 and shows a linear pattern, the rest of the transects shows R^2 value 0.85. The R^2 value fit well with shoreline category i.e. advancing and retreating shoreline classified based on the yearly change rate. The average shoreline movement within the period 1970 – 2014 is 150 m and maximum shoreline movement is 1958.17 m. The transect wise study shows accretion in almost all directions. The rate of accretion is much higher than erosion rates. Results show a very dynamic shoreline behavior.

VIII. CONCLUSIONS

In this study an attempt was made to examine the long-term morphological changes to assess the characteristics of deformations that had taken place in the Cochin estuarine morphology over the past 4 decades. Using multi-resolution satellite data along with the statistical techniques shorelines during different years around Cochin Estuary have been extracted. Results show a very dynamic shoreline behavior. The shoreline change rate computation was done by using Digital Shoreline Analysis System, an Arc GIS extension tool. All the calculations have been done using remote sensing and GIS techniques that fit with the empirical observations on the Estuary. Observed trends of the morphological changes generate concern in the background that the region may continue to remain vulnerable due to development pressures in the years ahead. The results obtained from this can be effectively used for long-term coastal zone management planning for the coming decades.

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