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FORAMINIFERAL CONSTITUENT IN MARINE SEDIMENTS – A PARAMETER IN SOME COASTAL ENGINEERING PROBLEMS*

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ABSTRACT

Foraminifera, among other microorganisms, form a major constituent of marine sediments and their composition is directly related to the nature of the substrate in which they are entombed. Past and the present data indicate that the size, test thickness, ornamentation, orientation and the degree of abundance have a correlation with the type of sediment and environment.

INTRODUCTION

While dealing with coastal engineering problems, the marine engineer is not only confronted with matters like design, operation and maintenance of various types of structures, but also with the sediments of the substrate, its porosity, permeability, material test, stability factors of foundation for harbour jetties, break waters, light houses and also deep ocean platforms. Therefore, it becomes all the more important and thus impossible to ignore, to have a correct knowledge of the sediment or substrate on which these structures appear. Hence, the prima faciefactor involved here is the proper understanding of the various components of the sediment found at different regions and the environmental factors that control their distribution. A few engineers like Tudor (1967), Keller (1967), Hironaka and Smith (1967), Vey and Nelson (1967) have emphasised the importance of sediment properties for foundation studies, while Field and Duane (1974) stressed the importance of a thorough knowledge of the various components making the sediment.

FORAMINIFERAL CHARACTERISTICS

Principally, among the biogenous components of the marine sediments, foraminifera form the major constituents of the skeletal remains preserved in them. They occur in intertidal to deep–water regions but their degree of distribution varies considerably, which depends upon the nature of the substrate and other physico–chemical parameters. Sometimes, it is observed that the beach sediment is wholly, and in some parts, partly composed of these foraminifera. Thus their contribution to the enrichment of the sediment by mass is very considerable. However, the kind of foraminifera differ from one regime to another, as also it differs geographically.

Foraminiferal content, abundance and distribution in various types of sediments such as sand, silt and clay and the intergrades, from the intertidal to neritic to bathyal to abyssal depths have been studied in great detail. Similarly, the different types of sediments are also classified in terms of their grain size and mineralogy. These two when viewed together give rise to the various zones (from the intertidal to abyssal depths) in terms of

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depth, temperature gradient, oxygen concentration, and the characteristic species distribution. Thus, it is established that certain species are found to be characteristic of certain sediment types, definite depth zonations, and tolerant to certain temperature gradients. Some species are also restricted to certain depth zones and they do not occur normally below or above those depths (e.g. *Bolivina hastata, Cibicides robustus*–90–120m; *Cassidulina curvata, Siphonina brydyana*–500–750m; *Uvigerina peregrina, Bulimina aculeata*–1600–2000 m). But the foraminifera critical of shallow depths, if found in deeper waters, then it is indicative of displacemet and transport of the sediment from higher to lower levels. Such deposits known as turbidites are commonly encountered in the present day seas and oceans.

The water temperature affects the absolute size of the foraminiferal test. The agglutinated forms become larger in size in colder waters, however, the calcareous forms grow likewise in warmer waters. In oxygen depleted waters they become dwarfed and resistent. Besides the hollow shells also get filled up with minerals like pyrites and glauconite if the environment becomes highly polluted.

FORAMINIFERA AND SEDIMENTARY TYPES

It is established that foraminiferal characteristics such as size, sphericity and roundness, ornamentation and shell thickness are directly related to the grain size, mineralogical composition, organic matter content and the type of bedding of the sedimentary type. This is indicative of the environmental conditions of deposition.

Thick–walled, more strongly ornamented foraminifera having sharp edges and keels are relatively predominent in the coarse–grained, massive sediments, while the thin-walled, unornamented, round edged, keelless foraminifera are more confined to the fine-grained, clayey or laminated sediments e.g., *Uvigerina canariensis* and *Bolivina subadvena* are unornamented and with rounded edges, and *Bolivina costata* without keels are found in fine–grained, clayey sediments, while the same species are ornamented having sharp edges and fully keeled when found in coarse sediments. Hendrix (1958) noted from the cores of Miocene sediments of Ventura and Los Angeles basins that *Uvigerina (Hopkinsina) magnifica* and *Bolivina decurtata* are unornamented and round edged in the laminated sediments while the same species were found to be highly ornamented and sharp edged when encountered from massive sediments. In the shelf sediments of Kerala Coast *Bulimina denudata* and *Bolivina acuminata* were found to be common having rounded peripheries and their median diameter was less than 0.125mm (Setty, 1974) as also reported from sediments of Santa Catalina islands, California (McGlasson, 1959).

Thick–shelled and strong foraminifera survive well in a high density and high velocity environment whereas a thin–walled, least ornamented form is preferable for a low velocity and low density environment. Consequently, many recent and fossil organisms are associated with specific lithologies, textural characters and bottom current velocities. However, a mixed fauna indicates mixed environment which is due to mobility resulting in turbidites.

It has been computed that the foraminiferal shell–thickness increases slowly with the increase in grain size upto approximately 0.025mm but later it increases rapidly with increase in grain size. Also, it increases with decrease in clay and organic carbon content in the sediment. Similarly, the foraminiferal abundance also increases with decrease in average grain size from 0·04 to 0·03 mm but progressively more slowly with decrease from 0·03 to 0·01 mm (Hendrix, 1958). Since the grain orientation in clayey, fine grained sediments is dense and porous, the foraminifera enclosed in them get compressed flat and so align themselves in orientation with the bedding plane. However, the skeletal durability in preservation, fragmentation due to physical and biological destruction, and loss due to chemical deterioration must be kept in view.

SEDIMENTARY REGIMES

Thus far, the morphological variations of foraminifera and their geological relations have been examined with respect to marine sediments and the variables in terms of their grain size, and textural pattern. These parameters are compatible with various marine sedimentary types of basins and other stratigraphic exposures on land.

The microfaunal content is found to be very high (30–40%) in the sediments off Pondicherry and Madras at a depth range of 99–201m (Setty and Rajamanickam, 1972; Setty, 1976a; 1976b). This indicated a rise and fall of the sea level. However, it is observed that the interrelationship of foraminifera to the substrate gets disturbed if the region is injected by various types of pollutants. In Cola Bay off Goa, the industrial effluents discharged into the sea increased the organic carbon in the sediments and drastically disturbed the stability and the sensitivity of the foraminifera through its morphology and distribution pattern which otherwise would have been normal (Setty, 1976c, 1976d). More examples can be listed from many other regions of the world. Thus the past and the present data indicate that the size, test thickness, ornamentation, orientation and the degree of abundance is directly correlatable to the substrate and the environment.

IN ENGINEERING PROBLEMS

Thus indicating the compatibility between the foraminiferal content and the substrate as a key in the deduction of the environment of any region. In view of this, the degree of foraminiferal constituent in a sediment which varies considerably must be taken as a major parameter in sediment analysis. The sediment as a whole, through its physical properties such as grain size, water content, wet density, and shear strength influences greatly the design of the structure. Such mass properties of the sediments depend entirely upon their various constituents and more particularly the skeletal remains (foraminifera) present in them.

It is in the interest of the marine engineer to ascertain before hand, whether the sediment at the site is unconsolidated, relatively recently deposited or whether it represents an older bedrock. The microfauna (particularly the foraminifera) of the samples collected indicate the nature of the sediment, its age, environment in which it was deposited and its nearness to the shore (when cores and other strata are considered.) This information will help him to design structures taking into consideration the magnitude, cost and other factors, so the foundation analysis indicates the bearing capacity of the sediment to support the structure satisfactorily. Similarly a knowledge of the initial conditions of sand, or clay deposit in terms of stress and density (related to its composition and biogenic constituents) is absolutely important before pipe piles are driven into the sediment (McClelland, Focht and Emrich, 1967).

Tudor (1967) is of the opinion that a deep sea mooring cannot be designed without an adequate knowledge of the bottom soil characteristics. This means that a thorough knowledge of the various components making it are essential.

The soft muds and oozes (of engineers, parlance referring to fine grained silts and clays having more than 30% biogenous material) have natural water contents above their liquid limits (in deeper parts of the ocean), hence, Tudor (1967) emphasises that the designer of dead weight anchors should consider carefully the ability of the bottom to support the submerged weight of the anchor in the bottom soil.

According to Keller (1967) the average shear strength values of the upper few feet of the sea floor sediments ranges from less than 0·5 to 2·5 lbs psi. The coarser sediments, in shallower water depths found closer to land, have low shear strength (<0·5) whereas those with increased calcium carbonate (including the skeletal remains of foraminifera and other calcareous microfauna) and low latitudes show higher values (0·5–1·5). The highest range of values (2–2·5 lbs psi) observed so far are in the calcareous oozes in the Pacific.

Foundation studies such as bulk density, penetrability and liquid limit at depth are conducted during the design stages of potential beach structure sites, however, aggregate properties such as beach firmness or degree of sand packing (as it is called) are highly relevant in the resistance of beach toward erosion (Krumbein, 1959).

Some of the coastal engineering potentials of marine sediments are placement of fill on beaches to check beach erosion. The erosion takes place because updrift source material either has diminished or because the fillmaterial becomes unstable under prevailing wave and current actions or because a beach is thrown out of equilibrium by unusual storms, hurricanes, cyclones or other events.

Therefore, the engineer needs to know about the behaviour of fill after placement and how it adjusts to the environment. As a result of firmness measurements, the engineer monitors the changing firmness by noting the soft spots and other irregularities (Krumbein and James, 1974). These soft spots formed may be due to high organic matter content, fineness of sand fill and also the larger component level of skeletal remains of hollow micro-organisms (foraminifera, ostracoda etc.) which are of low density, having high void ratio, highly porous, susceptible to compression and crushing and also their solubility characteristic. Further, these skeletal tests can easily be carried away by scouring action of waves, currents and removed through solutions. Thus beach firmness is lowered and reduced.

Since the sediments, either in unconsolidated or consolidated state are important in all coastal to deep sea engineering problems, a good knowledge of the foraminiferal constituent parameter of the sediments concerned will be of very great significance.

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REFERENCES

Field, Michael, E. and David B. Duane, 1974. Geomorphology and sediments of the inner continental shelf, Cape Canavaral, Florida. *Technical Memorandum No. 42*, Coastal Engineering Research Centre, 87 pp.

Hendrix, W. E., 1958. Foraminiferal shell form, a key to sedimentary environment. *Journal of Paleontology*, 32: 649 - 659.

Hironaka, Melvin C. and R. J. Smith, 1967. Foundation study for materials test structure. *Proceedings, ASCE Conference on Civil Engineering in the Oceans*, San Franscisco, 489 - 530.

Keller, George, H., 1967. Shear strength and other physical properties of sediments from some ocean basins. *Proceedings, ASCE Conference on Civil Engieeering in the Oceans*, San Franscisco, 391 - 417.

Krumbein, W. C., 1959. The "sorting out" of geologic variables illustrated by regression analysis of factors controlling beach firmness. *Journal of Sedimentary Petrology*, **29**: 575 - 587.

Krumbein, W. C. and W. R. James, 1974. Spatial and temporal variations in geometric and material properties of a natural beach. *Technical Memorandum No. 44*, U. S. Army Corps Engineers, Coastal Engineering Research Centre, 79 pp.

McClelland, B., Jr. J. A. Focht, and W. J. Emrich, 1967. Problems in design and installation of heavily loaded pipes, *Proceedings, Conference on Civil Engineering in the Oceans*, San Franscisco, 601 - 634.

McGlasson, R H., 1959 Foraminiferal biofacies around Santa Catalina Island, California. *Micropaleontology*, **5**: 217 - 240.

Setty, M. G. Anantha P and V. Rajamanickam, 1972. Heavy mineral suite in the shelf Sediments off Madras Coast. *Journal of Indian Geophysical Union*, **10**: 93-107

Setty, M. G. Anantha P., 1974. Holocene benthonic foraminifera from the shelf sediments of Kerala Coast. *Bulletin Earth Science*, 3 21 - 28.

Setty, M. G. Anantha P., 1976a. Foraminiferal assemblage at the continental margin regime off Pondicherry, Bay of Bengal. Seminar on Coastal Sedimentaries South of 18° Lat., Madras. Abst. p. 23.

Setty, M G Anantha P., 1976b. Recent foraminifera from the inner shelf off Madras, Tamil Nadu. Indian Geological Congress, First Session, Abst. p. 16 - 17.

Setty, M. G. Anantha P., 1976c Foraminiferal abundance in the modified marine environment of Cola Bay region, Goa. Colloquia Paleontology, Hyderabad, Abst. p. 43 - 44.

Setty, M. G. Anantha P., 1976d The relative sensitivity of benthonic foraminifera in the polluted marine environment of Cola Bay, Goa. Sixth Colloquia, Micropalctology and Stratigraphy, Banaras, Proceedings, p. 225 - 234.

Tudor, Walter J., 1967. Moorings and anchoring of deep ocean platforms. *Proceedings, ASCE Conference on Civil Engineering in the Oceans*, San Franscisco, 351 - 390.

Vey, Eben and R. D. Nelson, 1967. Environmental effects on properties of Ocean sediments. *Proceedings, ASCE Conference on Civil Engineering in the Oceans*, San Franscisco, 531 - 568.