Strategy of construction within the marine coastal zone in relation with coastal dynamics

Stratégie de construction dans les zones côtières marines en liaison avec la dynamique littorale

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Abstract: The coastal zone of seas and oceans has certain specific structures, trends and intensity of development which make it distinct from all other natural systems on the Earth. This also requires a special approach for development and construction in the coastal zone. Thus, on the basis of experience gained from coasts of different seas and states, a system of strategic measures including 16 main elements was formulated. It includes information data on construction, geographical localization of each sector of the coastal zone, corresponding methods of information analysis, harmony between the natural system and construction measures, maintaining the natural restoring potential of the coastal system, safe and effective exploitation of facilities under construction for a maximal period and ecologically friendly facilities. Integrated development of natural resources of the coastal zone seems to be not feasible. The type of economic activity should correspond to individual natural features of the coastal zone. Kinds of activity which contradict one another should not be permitted.

Keywords: Coastal zone - Sediment balance - Abrasion - Accumulation - Construction - Strategic system - Optimization of uses of nature

Résumé: Les zones littorales présentent des modalités et des rythmes d’évolution bien distincts des autres systèmes naturels terrestres ce qui implique une approche spécifique en matière de construction et d’aménagement. Ainsi, à partir de l’expérience de terrain, un système de 16 mesures stratégiques est proposé. Il comprend des données sur la construction, une localisation géographique de chaque secteur côtier, des méthodes d’analyse adaptées, un équilibre entre le système naturel et les décisions en matière de construction, la préservation du potentiel naturel de restauration du système littoral, des équipements sûrs et efficaces sur le long terme et respectueux de l’écologie. L’exploitation intégrée des ressources naturelles de la zone côtière ne semble pas être réalisable. Les activités économiques doivent être adaptées aux conditions naturelles locales et ne doivent pas s’opposer les unes aux autres.

Mots-clés: Zone côtière - Budget sédimentaire - Érosion - Accumulation - Construction - Stratégie - Optimisation de l’utilisation des ressources naturelles

The natural coastal system is a border environment between the land and the ocean. That is why it has characteristic natural features for the land, on the one hand, and for the ocean on the other, with mixed objects, factors and processes. The coastal zone is an environment for a concentrated cumulative influence of sea waves and wave currents. In most cases a very mobile relief develops and intensive transformation of sedimentary material takes place. At present the wave energy is sufficient for wave dredging of the amount of sediments which is an order of magnitude greater than that which exists. That is why about 80 % of the length of the ocean shoreline retreat at the different rates with a maximum of 10-20m annually. Mechanical morphodynamical and lithodynamical processes predominate. These features of the coastal zone have allowed to work out a special strategy of different types of construction and development of coasts.

This strategy is based on the study of the processes and forms of interrelation of natural and anthropogenous factors for attaining optimal natural usage under the influence of construction in the past, present and future. Optimization of nature usage includes two main parts: a - to keep the restoring potential of coastal morphodynamical and lithodynamical processes in this complex system; b - a safe and effective exploitation of the facilities under construction for a maximal time period. These principles are based on valuable information received by using instrumental methods in natural conditions during a sufficiently long time period, checking and tying them with logical, mathematical and physical modelling. The principle of geographical localization has been considered according to which each sector of the coastal zone is strictly individual in structure,
direction and intensity of development. The greatest efficiency of the recommended strategy of construction is achieved by using all above-mentioned integrated activity.

I - THE MAIN FEATURES OF THE COASTAL SYSTEM NATURE

When considering the nature of the coastal zone it is necessary to determine first which elements and components are priority in elaborating the strategy of construction. Absolutely all elements and components of the coastal zone should be distinguished into two groups.

The first group includes general planetary elements and components with which natural conditions, factors and processes are connected. They are represented by the borderbelt geographical position of the coastal zone between the land and the ocean, the dominance of relaxation of mechanical energy of sea waves and wave currents, secondary significance of chemical-biological processes, general sediment deficit in the coastal zone of the World Ocean, a predominance of destructed and retreating shores, dismembering of the coastal zone into separate lithodynamical cells and close interdevelopment of the nearshore bottom and shore as an entity.

It is feasible to include into the second group strictly local elements and components of the coastal zone according to the law of natural geographical zonation and the law of geographical localization. For dominating mechanical processes due to relaxation of sea wave energy, the geographical zonation is minimal and often has no practical significance during construction, however, it is maximum in wave absent processes: chemical, biological, thermic, gravitational, wind, etc. As to geographical localization is ascribed to the historic individual features of each comparatively small sector along the coastal zone length. This sector is usually a whole natural system where morphodynamical and lithodynamical processes are closely interrelated and interact with adjacent similar systems. An example of such a system is the alongshore lithodynamical cell. Each cell is strictly individual in its development and is characterized by specific dynamics, qualitative and quantitative values for sediment balance, and is not similar to others and requires a separate analysis for determining the strategy of construction, planning and management.

Coastal zone dynamics within the shore drift cell is determined by long-term stationary observations by using integrated, direct and sensory instrumental methods. From experience it has been shown that the length of these observations supplying information for optimal development and construction in the coastal zone includes the time of the elementary rhythm (11 years) with part of the former and latter, but not less than 15-20 years. However, the entity of all elements of the coastal zone with its emerged and submerged elements should be taken into consideration.

Estimations of sediment balance have shown that at the contemporary state of development of the ocean, the coastal zone is lacking in sediments. The energetic potential of the coastal zone is generally sufficient for complete wave movement of about 150.10^9 t annually of sediments of different origin and composition. It is 4-5 times greater than what actually dumps from all sources. That is why an excess of energy causes an absolute dominating of destructive processes. This is shown in the dominance of wave abrasion of different types and forms. Besides, the non-wave processes enhance or retard the abrasion processes in different lithodynamical cells to a certain degree.

For determining the strategy of construction in the coastal zone of the sea, the rates of abrasion of cliffs and benches have the greatest significance. Also the distribution of rates along crossing profiles and time, the interaction of shore and bottom abrasion, manifestation of non-wave abrasion should also be taken into consideration. It is also necessary to know the linear and volumetric dimensions of beaches and larger accumulative forms, numerical values of accretive processes of different types (wave, aeolian, biogenic, etc.). Estimations should be made as to positive and negative elements of sedimentary material balance within each cell. All of these factors and processes require instrumental measurements during an optimal time.

The main features of the coastal zone described above allow us to distinguish the main elements of strategy and management of construction of the coastal zone of the ocean. It is necessary to ascertain that any kind of construction is an anthropogenic disturbance in the natural systems.

II - ELEMENTS OF CONSTRUCTION STRATEGY IN THE COASTAL ZONE

From experience it is known that on relatively settled shores, construction does not have a negative effect within the limits of the given cell. Due to geological composition, values of the wave-
energetic potential and sediment reserves, the abrasion rates in stable (or hard) shores do not exceed 0.2 m/year. Of greatest significance for elements of strategy are very dynamic shores composed of weak and non-consolidated rocks and deposits.

**Information data**

Any type of coastal zone development is based on information on the environment. The objective of the substantiation is an assessment of the structure causing a corresponding change in the natural system in conditions of exploitation of the constructed facilities. That is why the first step in making strategic decisions is creation of an information base for planning and management on the basis of data already received and from long-term monitoring of morphodynamical, lithodynamical, hydrodynamical and non-wave factors, processes and objects.

**Corresponding methods of investigation of the level of natural systems organization**

The natural system in the whole and part (cell) in the coastal zone being tied with adjacent systems and having its own structure is subject to temporal changes. Each system takes up a certain area and responds to a natural rhythm of a certain length with greatest volume. For this type of system at the background rhythm is greater than "its own". The latter is characterized by a specific structure of shorter rhythms. Each then acts on systems of different scales. This spatial-temporal unity creates a level of organization of coastal natural systems.

This level of organization determines the selection of the method of investigation and the degree of reliability of the results obtained. It is not possible to use the method of investigation of long natural processes (for example, geological scale) for short-term processes for the length of one storm, one season or year. The method of studying mechanical processes in coastal zone is not compatible for studying chemical, thermic or gravitational coastal processes.

**Diagnosis for the whole system**

The coastal zone is made up of alongshore lithodynamical cell of different types. Each cell is one organism where all mechanical processes are closely tied. Antropogenic disturbance in one part of the cell is felt within all of its parts. That is why investigations and engineering prospecting for any construction corresponds to the natural zone when not only it is conducted on a small construction site, but within the frame of the whole cell. For determining the degree of influence of the facility on the coastal zone and the effect of natural conditions on exploitation of the facility in the future, an adequate opinion should be made on the manifestation and interaction of natural processes within the borders of the whole lithodynamical cell.

**Multifactors of development and integration of approach**

On the whole the coastal system and its components certain to the interface environment between the land and the ocean. That is why it bears the natural elements and components : the land, the ocean, mixed from the interaction of land and ocean. The overlevel shore and nearshore slope should be considered as an entity as they together make up the coastal zone. Factors, processes and objects of the atmosphere, hydrosphere, lithosphere and biosphere including the anthropogenous factor interact here simultaneously. For this reason the natural substantiation of the project with the coastal zone should be integrated. The high quality of investigations, planning, management and use of the coastal zone resources may be achieved by highly qualified specialists in all of these factors, processes, components and objects.

**Natural investigation priority**

Construction in the coastal zone occurs as penetration of a foreign body into a natural evolutionary system and creates an unexpected anthropogenic disturbance. The best quality, reliable and integrated information is received as a result of direct natural observations and experiments in the coastal zone itself. This kind of information provides for optimal location, structure and exploitation of the construction facilities according to technical, ecological, economic and aesthetic characteristics. Laboratory experiments, logical, mathematical and hydraulic modelling are recommended for use as additional means or for supplementing natural information.

**Geographical localization of coastal zone sectors**

As any natural system, the coastal zone is characterized by its own pertinent structure. The alongshore lithodynamical cell may be used as the main structural unit. Each of many cells is characterized by individual morphology, dynamics, hydrodynamical regime, sediment balance, non-wave factors manifestation, and consequently, individual direction, intensity and genetic
composition. Conclusions on the interaction of natural and anthropogenic processes in one cell may not be applied to other cells according to the law of geographical localization.

**Prospects of construction activity**

Natural mechanical processes in the coastal zone occur relatively slow. The accumulation of complete and reliable information in natural conditions is also long. However, this time period of 20 years does not suit the construction workers who try to build the facilities as quick as it possible. And the time for engineering prospecting is limited. Nevertheless, there are perspective plans of regions and periods for construction. They should be used for preliminary observation on the relief dynamics and the movements of sediments, so that towards the beginning of construction there may be available data on the morphology and dynamics of the coastal zone within the whole lithodynamical cell.

**Observing the objectives and issues of construction activity**

Any construction in the coastal zone should meet the objectives and issues for which it is being carried out. And nothing more should be required. However, the ways of response of nature to this construction may be different even unpredictable. As a result, side effects occur, mostly negative. That is why planning, management and construction need an elaboration of possible side effects in different lithodynamical cells in different physical-geographical conditions.

**Multifunctionality of construction facilities**

Experience has shown that different facilities in the coastal zone are sustainable and efficient, when they fulfil two or more functions. Coast-protective structures are designated for ceasing the destruction of the shores. At the same time, a construction should be selected which would deposit sediments on a part of the coast, would relax wave action, conserve biocoenoses, clean sea water from pollution, save the stability of accumulative forms and would make available a friendly environment for humans.

**Record of coastline retreat**

According to the contemporary nature of the World Ocean coastal zone, the shorelines retreat in most cases. Construction should be carried out in regard to abrasion rates and capitalment class of the constructions. If the facility in the coastal zone has a safety warranty (capitalment class) equal to 25, 50 or 100 years then it should be located at a distance from the shore which would withhold it from abrasion during the guarantee period. The facility on the coastal seabed should take into account the rates of nearshore bottom abrasion and dimensions of vertical deformations of the relief during extreme situations.

**Not to create other problems**

There are sites with different stability and dynamics within the limits of alongshore lithodynamical cells depending on concrete conditions. It is necessary to choose the most favourable parts from the point of view of dynamics. That is why a complete construction of the coastal zone is considered not feasible. Construction on very unstable and dynamic parts of the coast with high rates of shore and nearshore slope abrasion should be avoided. In the future this would help in avoiding the heavy expenditure of long-term operation of the facilities, including the cost of exploitation of coast-protective structures, settlements with their infrastructure, roads, lighthouses, jetties etc., which may exceed their estimated cost manyfold. Their will cause the greatest damage to the natural system.

**Nature should rest also**

For lessening the anthropogenic stress on the coastal systems, the whole coastal system should not be developed and subject to economic activity within the limits of the lithodynamical cell. Up to 40-45 % of the shoreline should remain natural, not built over and should be used as parks, reserves, touristic zones and rest areas.

**Not to damage ecological properties**

Due to dynamics, high wave-energetic potential and biodiversity, the coastal zone has a high capacity for assimilating and neutralizing pollutants and for retaining its high ecological properties. But in the past decades a tendency has been noted for the construction of some facilities in the sea farther away from the coast. These include jetties, platforms, piers, artificial islands and terraces, differently designated territories, sediment dumps, etc. Correspondingly, the "frontal line" of human activity displace into the sea in total. It begins to destruct the coastal system from natural development with its high assimilative and purifying capacity. As a result the environment may be damaged so much as to destroy the formation of valuable balneological
resources, the natural hydrochemical barrier on the path of pollutants washed from the land to the ocean.

**Think of the future climate**

In the next century, the climate changes have been predicted which may cause a restructing of the World Ocean water balance. A water level rise is anticipated from 0.6 to 3.45 m depending on the method of prognosis. During planning and management of construction in the coastal zone in the next decades the location and dimensions of sites should be determined which are not subject to passive flooding and enhancing of abrasive processes as the sea level rise under the greenhouse effect impact. Public awareness should be aroused to constructed potentially dangerous parts of the shore.

**Financial and material feasibility**

Non-durable rocks and deposits which are intensely destroyed are widespread in the coastal zone. Under the influence of a sediment deficit, a rise of wave energetic potential, intensive sea-level rise, the destructive processes within sectors of non-durable distribution are anticipated to occur. The construction of protective structures may be a response. However, material, financial and labour resources should be used first of all when material and heritage values of the protecting lands and facilities will be higher than the cost of construction and exploitation of protective constructions and structures.

**Harmony between nature and man**

The ocean coastal zone is so attractive to human activity that it is felt in all elements of the coastal system, quickly and immediately. But an integrated multiobjective construction and use of natural properties and structures of the coastal zone appears to be not feasible, not sustainable. This kind of use increases the anthropogenic load which very quickly drains natural resources and disturbs the self-restoring potential of the ocean coastal zone. It has been recommended to conduct those types of construction and economic activity which correspond most to concrete natural properties of a given lithodynamical cell, which do not contradict one another.

**Conclusion**

The natural system of the coastal zone develops under the influence of mechanical energy mostly. The source of energy is the ocean. The source of sedimentary material is the land previously. Part of this material is formed in the coastal zone. At the contemporary geological historic stage of the coastal zone is position with an acute sediment deficit. Dominating are destructive morphodynamical and lithodynamical processes which predetermine the main elements and principles of construction strategy.

Two groups of elements and components of the coastal system can be distinguished. The first includes general planetary which are linked with natural conditions, factors and processes influencing the strategy of construction. They are baseline in relation to the second group which include local natural conditions, factors and processes. They, to the greater degree, influence the choice of strategy of construction corresponding to the law of geographical localization. The objective of this strategy is the optimization of nature usage, taking into account construction in the past, present and future. Meanwhile, the degradation of the restoring potential of the coastal system should be avoided. Efficient safe exploitation of the facilities should be conducted for a maximum length of time.

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