IMPACT OF SEA-PORTS CONSTRUCTIONS ON DYNAMICS OF CONNECTED NATURAL SHORES WITHIN UNTIDAL SEAS

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ABSTRACT

Natural conditions of building and exploitation, sea-ports and port constructions are different for tidal and untidal seas. Principal differences are as follows: in the coastal zone of untidal seas, there are no essential tidal sea-level fluctuations including those of large amplitude and there are no reversible tidal currents. Tidal flats and muddy alongshore flows of drifts occur seldom. Differences of tidal characteristics influence the choice of construction and the nature of port configurations. An acute deficiency of drifts in the coastal zone poses the greatest danger for connected shores after the completion of port-related constructions (e.g., jetting, canals, piers).

For untidal systems (amplitudes less than 0.5 m), ports can be divided according to environmental conditions into those which are situated: a) in harbours with shallow nearshore water depths, b) in harbours with deep nearshore water depths, c) in lagoons and limans, d) in river estuaries, e) on smoothed deep nearshore bottoms, and f) on smoothed shallow nearshore bottoms. Different combinations of the variants mentioned above are possible. Ports from a, c and f deserve the greatest attention. Ports developed in these environments require numerous and expensive construction and offer the greatest potential impact on connected shores.

In this work conditions ofa, c and f types of environments are analyzed. Under such conditions outer portal constructions (piers, jetties, navigable canals, moles, etc.) represent artificial obstacles for sediment drift movement. These structures promote redistribution of drifts in the coastal zone and alter conditions of development of connected natural shores.

1. INTRODUCTION

In contemporary economic practice, the location for sea-port construction is chosen mainly on the basis of economical expediency. But there is one more important thing.

The volume of sediment and mass of rock which must be transported during the construction of foundations, roads and navigable canals during deepening of a port's user area can be taken into account in the shallow nearshore bottom case. Closeness of roads and railways can also be taken into account. At the reconnaissance stage, usually the place on the shore where the port is to be situated, and short sections up to 1-2 km in both directions along the shore, are investigated. At the same time, in most cases, the way in which the port will influence connected shore systems, and the way in which these shores will influence the conditions of outer portal construction utilization, are not taken into consideration. Mutual impact is revealed after the port has been constructed and supplementary modifications can require considerable additional expenditures.

2. PORTS AND NATURAL ENVIRONMENTAL CONDITIONS

The analysis of conditions under which sea-ports are constructed has shown that these characteristics can be systematized into several groups. First of all, conditions on tidal and untidal shores differ greatly. Among the natural differences are the following: in the coastal zone of untidal seas, there are no essential tidal sea-level fluctuations, including those of large amplitude and there are no tidal reversible currents. Tidal flats and alongshore flows of muddy sediments occur seldom and the width of the surfzone is narrower. These and other characteristics can influence the choice of the construction place, building the nature of practices and of constructions, and the sea-port's future utilization.

On the shores of untidal seas (amplitude less than 0.5 m), it is important to take into account a number of natural conditions while choosing a place for port construction. Construction sites can be divided into those which are situated a) in harbours with shallow nearshore bottom, b) in harbours with deep nearshore bottoms, c) in lagoons and limans, d) in river estuaries, e) on smoothed deep nearshore bottoms, and f) on smoothed shallow nearshore bottoms. These variants are the basic ones, but in practice they occur most frequently. However various combinations of the given variants are possible (e.g. if the port is situated in a river estuary and the river flows into a deep harbour or along a section of smoothed shallow shore.

The study of different natural conditions in regions where ports are situated allowed confirms that variants (a), (c) and (f) are of particular importance. It is under such conditions that the most active changes to the coastal zone caused by the impact of hydrodynamic and lithodynamic processes on untidal seas take place most often. It is clear that changes are also considerable in river estuaries, especially those of large rivers, but these changes are caused mainly by fluvial and not by wind-wave processes.

Harbours location in shallow shores environments (e.g. lagoons) are convenient because the ports built in them are protected against stormy waves. However, these settings require a considerable amount of development work to increase natural water depths. The problem of the utilization of great amounts of rock, of strengthening harbour shores after depth increase, and of construction of stable berth walls arises. Besides, in such conditions, the water area of the port must be joined with the open sea by a navigable canal which means additional dredging. As a rule, such navigable canals must be surrounded by jetties to give protection against sea waves and currents. If the shoreline is sinuous and changes little with the course of time, drift supply to the coastal zone is not large and under these conditions, port utilization in shallow harbours is relatively favourable. A small supply of drift into the anchorage area of the port and into the navigable canal favours port development. As a result, depths are stable and change little with time. If the volume of drift in the coastal zone is relatively large, a considerable amount of it will be carried into the canal and port's anchorage under the influence of sea waves and currents; water depths will decrease quickly. In this case, the necessity to build jetties not only against storms but also to prevent port basins from filling with sediments arises. Exceptionally large volumes of drift is supplied in cases where a river carrying a large drift load flows directly into a shallow harbour, or into the basin area of the port. The ports of Ventspils, Pavilosta and Pyarnu on the Baltic Sea can be cited as examples of this category. Such ports constitute about 15% of the world's total. Natural conditions associated with ports in lagoon and liman environments have their positive and negative sides. At the same time, there, exist inconveniences, mainly expensive maintenance works connected with the deepening of lagoons and limans, and with the construction of a navigable canal. According to the butyryl peculiarities of lagoon and liman types of shores (Bird, 1953; Shuisky, 1986; Zenkovich, 1962) shoreline retreat is one of their characteristics. This is why the additional problem of protecting outer portal constructions from destruction of their flanks arises. The question of what to do with the masses of rocks which appear as the result of the deepening of a liman or lagoon water area, and of navigable canal construction, is also unfavourable. These masses are mainly represented by mud saturated with salts. A great amount of such masses also appears during the construction of berths, access roads, communications, and buildings on the shores of the liman or lagoon.

Liman and lagoon shores have smooths or almost smooth shorelines. The shores themselves are most often composed of low resistant rocks, mainly of a clayey or sandy nature and less often, of sandstone, limestone, marls and materials of similar strength. This explains why the shores adjoining portal jetties and navigable canals can change quickly when subjected to severe abrasion. Conversely, smoothness of the shoreline is the basic condition of development of alongshore drift flow. As a result, protecting jetties and navigable canals that are under the impact of alongshore drifts movement is important. This drift transport phenomenon ensures distribution of drifts along the shore, is conducive to the maintenance of accretionary forms (first of all beaches), connects areas of drift source with sections of drift accumulation. The installation of man-made constructions causes discordance with respect to natural processes and this is not always favourable for natural of coastal zone systems or for exploitation of the constructions themselves. About 20% of world ports fall under such conditions.

At last, natural conditions for port construction on open smoothed and shallow shores must be considered the least suitable alternative. Like those of limans and lagoons, these shore types are composed of low-resistant deposits and rocks, are sensitive to wave impact and alongshore drift flows develop along them freely. But there does exist some difference: the importance of river drift is more noticeable, is rivers usually flow into the sea along such shores. The other difference lies in the fact that it is necessary to build protective constructions, not only for navigable canals, but for port basin areas as well. These protective constructions create more noticeable obstacles for drift distribution and are therefore able to cause more change to the morphologies and dynamics of connected shores. At the same time, connected shores cause more difficulties for ports and port structure utilization than in variant (c) and still more than in type (a). The necessity of acute quantitative estimation of drift mass balance within lithodynamic systems ("cells"), values of shoreline retreat and growth, beach dynamics, shore changeability in the course of time represent some of the key inherent problems associated with this kind of shore.

The described here peculiarities of various natural conditions in which sea-ports can be built and can function show that there exists a number of aspects of port construction that leads to interaction with natural processes in the coastal zone of untidai seas. The study of drift mass balance in the coastal zone, of sediment utilization and of portal construction impact on connected shores is of the greatest importance.

3. DETERMINING THE BOUNDARIES OF ALONGSHORE CELLS

Before constructing a sea-port, a study of the morphology and dynamics of the designated coastal zone area is carried out. Such a study is of the greatest importance in natural conditions (a), (c) and (f). It is carried out in order to exclude negative impact on the environment, and to insure the cheapest, the longest and the most reliable future utilization of the sea-ports. In this case, determining the condition of alongshore drift flow, in particular its volume, is of considerable interest. This parameter is particularly important as it assists in understanding the processes of portal water area and navigable canal infilling, shore dynamics at the location of port construction, impact of constructions on connected shores, and the impact on the natural development of lithodynamic systems ("cells"). Direction of drift flows, their change in time, depths of the most active movement of drifts, and wave base must also be determined.

Volume of drift flow means the real quantity of drift carried through the cross section of the coastal zone per a unit time. It is defined as the algebraic sum of separate storm portions of drift moving along the shore in one or another direction (Zenkovich, 1962). According to this definition, it is first necessary to calculate the direction and energy potential of alongshore wave energy flow and wave currents. As on untidai seas, windy waves represent the main type, and calculations are done using the wind, taking into account wave momentum, sea depth and depth gradient, and the angle of windy waves approach to the shoreline (Knaps, 1968; Krylov, 1986; Zenkovich, 1962). At the same time, average velocities along certain directions are taken into consideration, and dynamical, not the geometrical length of wave momentum is also included. The energy (E) calculation is carried out by the formula whose general notation is as follows:

$$E=/CS^{3}/\hat{}2\sin\text{«}\cos\text{«}$$

where: K is the coefficient depending on particular natural conditions, S is the average point wind velocity (m/sec), F is the relative duration of the wind at a particular point, D is the length of the momentum of waves at this point in km, *a* is the angle between the wave's ray and the shore direction in front of the entrance to the coastal zone. Calculations of E for 8 or 16 points is done and the resulting vector E is calculated by the geometrical method. E shows the energy potential of alongshore energy flow. Mapping E onto the tangent to the particular point of the shore gives the directional value of prevailing energy flow T_r. This prevailing direction is divided into drift transport factors +T and -T (Knaps, 1968; Longinov, 1966) which carry drifts in one or another direction along the shore in the average per unit time (year). In order to determine the values of +T and -T, a perpendicular to the tangent is drawn. The amount of energy passing from the right side (relative to the perpendicular) to the shore is denoted as +T, from the left side as -T. Their algebraic sum gives T_r, as mentioned above. Most of all T_r is significant and its largest value characterizes the greatest drift moving capability of energy flow as well.

However, calculations of energy potential and of alongshore energy flow direction in themselves do not allow an estimation of the real quantity of drift which is transported in one or another direction along the shore relative to the shoreline's perpendicular. There exist several methods of translating the amount of energy into the amount of drift (Caldwell, 1956; Komar, 1976; Monochar, 1955; Watts, 1953). All of the above investigations show that the quantity of drift transported in the coastal zone is directly proportional to wave energy and to the factors that influence the dissipation of energy. Since waves are generated by the wind, many studies have concluded that: wind direction and velocity directly influence the direction and dimensions of waves, and of currents velocities in the coastal zone. These, in turn, influence the direction and intensity of drift movement (Ingle, 1966). A similar conclusion is verified by some of the latest investigations (Aibulatov, 1989; Leontiev, 1989). In this connection it can be stated that nature of drift distribution is closely connected with the distribution of +T and -T relative to the perpendicular from a point on the tangent. The algebraic sum $(+T) + (-T) = T_r$ per a year, according to the definition by V.P. Zenkovich (Zenkovich, 1962), shows the direction of drift flow, and the absolute value of T_r shows the volume of the flow.

The ratio of E and T_r, and their exposition with respect to the shoreline, allows the determination of the boundaries of the alongshore lithodynamic cell. Corresponding methods can be found in the works (Shuisky, 1986; Shuisky *eta/,* 1983). Such a cell occurs within the section in which one alongshore drift flow acts. This cell is denoted by the totality of calculated +T and -T values, having the vector of one direction within a segment of a coastal zone of various length. Local and short term change of the resultant of the alongshore drift moving force T_r is connected to shoreline changes or changes of submarine relief from place to place can occur within a lithodynamic cell. But a change of the direction of T_r on the neighbouring section of the coastal zone means that other alongshore lithodynamic cells exists here (Inman, 1973; Pierce, 1976). Thus the transitional section, where the direction of the resulting vector T_r changes into the opposite one, is the boundary between two lithodynamic cells. It happens that the direction of the wind is the same in the transitional section but there is a considerable break in the shoreline between the two cells. In all cases, the composition of drifts, the dynamics of coastal relief forms, sources of nourishment and their productivity, etc. are all important indicators of cell boundaries.

In each cell, alongshore flow of drifts is characterized by very definite parameters of sections in regard to generation, transit and accumulation (Shuisky, 1986). Having determined the boundaries of the cell, it is possible to discuss the calculation of drift balance.

4. DRIFT BALANCE RESULTS

At present, the suggested methods for calculation of drift flow volume (and with the help of these calculations the prediction of the filling of port water areas and navigable canals with sediment) do not take into account the quantity of drift which is really in the coastal zone. This statement applies to all the methods used in conditions (a), (c) and (f) (see: Caldwell, 1956; Longinov, 1966; Monohar, 1955; Watts, 1953). Construction of every port must proceed under stated conditions within a definite lithodynamic cell. In each such cell, the average of sediment sources of drifts supply during long periods are definited.

Because each alongshore drift flow is in one cell, and because in the same cell there is also a definite number of drift sources with definite productivity, it is reasonable to calculate the total mass of these drifts using the method of mass balances. This method is documented in (Shuisky, 1986; Shuisky *eta/,* 1983; Shuisky *eta/*1989). It allows the determination of how much sedimentary material is supplied to the coastal zone within a lithodynamic cell as the result of the abrasion of shores and of nearshore bottom sediment under the influence of river drift flow, biogenic and chemical differentiation. A calculation of the amount and composition of sediment can be made for two groups of drifts: 1) traction, which remain in the coastal zone; 2) suspended which are carried out. All calculations are brought to a specified unit of time, usually a year. The results of these calculations are closely related to the contemporary dynamic of relief and to drifts within the boundaries of each cell. Such investigations must be carried out simultaneously for a long period. It is also necessary to measure the composition of deposits and sediments on the shores and nearshore bottom, and the biologic mass of benthos. Calculation of alongshore flows of average seasonal wave energy, during a year, and during a long-term period should be carried out. Dependence of the quantity of transported drift on the nature of the distribution of wave and current's energy for each cell must be stated. For a example, take one of the alongshore lithodynamic cells in the coastal zone of the Black Sea Between Adjiask Cape and Odessa Bay (eastward from Odessa city). Its length is 56 km. 23 observation sites were established here in 1956 and the study of all natural parameters mentioned above were carried out. The list of all sources of drift has been composed e.g., abrasion of cliffs and beaches, biogenic processes (Shurisky, 1988). Other sources are not important, Data of long-term stationary observations showed that the average rates of clayey cliff abrasion were from 0.58 to 2.1 m/year, those of nearshore bottom were from 0.09 to 0.032 m/year. Biological mass of benthos in nearshore water was from 150 to 360 3 g/m^2, among which the mineral part (valves of mollusc shells) constituted from 16 to 68% of the total mass; on the average 40-55% of that was related different species of molluscs. A stationary study of eolian processes showed that, on the average, 1-2 kg of sand per 1m of length is fluxed from sandy accumulative forms into the sea under the influence of wind. In fact, from several grams to 20-30 kg of sand can be moved during an hour from a i m length depending on the velocity, direction, duration and recurrence of wind, composition and humidity of drift, relief of vegetation, and landscape structure of accumulative forms.

Within the studied lithodynamic cell, all sources mentioned above supply 1,750 million m^3/year of sedimentary material of various composition into the coastal zone. In the coastal zone, all of this amount of drift is subjected to mechanical and chemical differentiation and primarily into two sedimentologic groups: traction and suspended. This material is graded, suspended in water, carried by wave currents out of the coastal zone and into the sea or limans; it forms eolian forms on the shore. Drifts coarser than 0.1 mm prevail on beaches, drifts finer than 0.1 mm constitute only from 0.1 to 2.6% of the total. It turns out that the part of drift deposits coarser than 0.1 mm remains in the coastal zone and is included into the composition of beaches and barriers. The part of the drift finer than 0.1 mm is carried mainly into the sea.

The amount of drift coarser than 0.1 mm forms the annual budget of coastal zone sediment and during long intervals it constitutes an average of 130,000 m^3/year; extreme values in some years being from 90,000 to 250,000 m^3. This budget is distributed depending on the ratio of opposite flows of wave energy +T and -T along the shore with respect to a line perpendicular to the general direction of the shore. Between Adjiack Cape and Odessa Bay, the percentage values of +T and -T were 79:21 to 53:47 on average within the lithodynamic cell; T_r is considered to be 100%. This means that more energy is usually spread from east to west than from west to east. Considering the conclusion stated earlier regarding the direct dependence of the quantity of transported drift on the amount of wave energy, drift forming the annual budget within a lithodynamic cell characterized by settling conditions must be distributed according to the same ratio (+T):(-T). Consequently, in different years, from 79% to 53% of the entire budget must move to the east; 21 % to 47% moves to the west. This kind of analysis corresponds to the definition of alongshore drift flow. The algebraic sum (+T) and (-T) in this case gives values from 8,000 to 76,000 m^3/year, taking into consideration the average budget. Considering maximum and minimum values for the budget in different years, the algebraic sum (+T) and (-T) will constitute from 6,000 to 145,000 m^3/year of suspended sediment drift. In the end, this entire amount is moved by alongshore drift flow to the accumulation site in Odessa Bay and sediment from the source area is supplied in its place. This process ensures rotation of drift in the lithodynamic cell through the effect of the drift flow process.

The calculation of the drift budget mentioned above was carried out using the mass balance method; calculations of (+T) and (-T) were carried out using the method of P. Knaps (Knaps, 1968). The algebraic sum of (+T) and (-T) can be identified through comparison with the volume of alongshore drift flow. Its value was checked by natural observation of processes of traction drift sediment accumulation in the coastal zone. For other conditions, other methods of calculation can be used to determine the propagation of wave energy (Caldwell, 1956; Longinov, 1966; Monohar, 1955; Watts, 1953).

The Black Sea port of Yuzhniy was built in 1974 in the middle part of an alongshore lithodynamic cell. Port water area and berths are situated in the liman and the liman is connected with the sea by a navigable canal which is 15 m deep and 200 m wide. The canal is protected by jetties from both sides and the moles reach a depth of 5 m. Observations carried out over 15 years showed that the navigable canal is filled with inequigranular sediments, their amount being from 110,000 to 120,000 m^3/year. The content of the fractions coarser than 0.1 mm in the canal ranges from 45 to 55%. Therefore from 49,500 to 66,000 m^3/year of traction load particles were accumulated in it since 1974. This amount constitutes from 38% to 51% of the annual norm of the drift budget. This indicates that in different years, a considerable part of coastal drift is lost from the coastal zone and does not reach the beaches.

In additions, drift has begun to accumulate between the shoreline and eastern jetty, as seen in other locations (Bruun *etal,* 1988; Zenkovich, 1962). During 1974-1988, more than 200,000 m^3 of sand and coarser sediments (with less than 3-5% of fractions finer than 0.1 mm) accumulated at a rate of about 15,000 m^3/year, i.e. representing about 11-12% of the average annual budget of beach forming fractions. Thus the outer constructions of Yuzhniy port intercept from 50 to 62% of the annual drift budget from the alongshore cell. Therefore, this material is not available to feed beaches. As a consequence, the dimensions of beaches must decrease which lessens their capability to protect the shoreline.

In fact, before the construction of Yuzhniy port, within the entire lithodynamic cell located at the bottom of abrasion cliffs, the average width of the associated sandy beaches was 20.6 m; their height being 1.14 m and the amount of drift of recognizable morphology was 21.1 m^3/m. However, after the construction of jetties and the canal, according to the measurements of 1986, the average width of beaches was 11.4 m with a height of -0.96 m; the amount of drift was only 9.7 m^3/m. This change implies that conditions for stronger influence of sea wave on abrasion cliffs had developed. Annual values of wave energy (E) during the period from 1968 to 1988 were calculated. They indicate that E decreased in general and that the decrease of energy potential constituted about 20-25%. Such a phenomenon is explained by the long-term recurrence of wave regime which was unable to influence the increase of cliff abrasion rates or the peculiarities of the physio-mechanical properties which characterized the shore face. A decrease in volume and linear dimensions of beaches remains as the main cause.

Before the construction of Yuzhniy port, the rate of cliff abrasion at all 23 observation sites was, on the average, 0.94 m/year (0.35 to 1.66 m/year). After port constructions were completed, the average rate of abrasion within the lithodynamic cell was 1.64 m/year (0.20 to 2.71 m/year), i.e. 43% greater. This increase led to additional losses of nearshore territory. Before 1974,. abrasion processes destroyed, on the average, 4.9 hectares within the whole cell; after the construction of the port, the average increased to 8.0 hectares per year.

Data discussed above show that the balance of drift can be calculated and how it can be done, how to study changeability of different elements of the balance after sea-port construction, and what damage to the nature of connected shores the construction of the port can cause. Such conclusions can be achieved if the whole lithodynamic cell, and not only the place where the port is built, is considered.

5. SHORE PROTECTION IN AREAS OF SEA PORTS

After the construction of the navigable canal and jetties, drift from the eastern side of the eastern jetty started to accumulate on the smoothed shore of Yuzhniy port. Accumulations of about 50-60% of the average annual budget of drift in alongshore cell (in the canal and near the eastern jetty) was, accompanied simultaneously by a sharp decrease of drift volume from the lee side near the western jetty. This deficit led to the activation of abrasion processes in areas where numerous constructions are situated on the shore. Rates of cliff retreat were 3 times greater than average values; downfalls and landslides also became more frequent (Shuisky ***et al,*** 1988). There were different opinions as to how to prevent abrasion of the lee side of the shore near the western jetty of Yuzhniy port (Bertman ***et al,*** 1983). First of all, some specialists foresaw bypassing. But bypassing would have caused the activation of abrasion processes near the eastern jetty, since under natural conditions this part of the coastal zone has a considerable deficiency of drift. Groins and moles were suggested, but under conditions of drift deficiency they cannot promote accumulation and beach growth. It is expensive to create artificial beaches, and besides this solution would have caused damage to landscapes in the places where the sand would be mined. Other ways of shore protection also proved to be unacceptable for different reasons. At the same time, as the result of deepening of the water area of Yuzhniy port, construction of the canal and fattening of coastal slopes of the liman where the port was built caused a great amount of deposition, mainly clay and fragments of limestone appeared. Their total amount was about 2.5 million m^3. This posed a problem of what to do with these sediments. All of the land near the port is used for agriculture. To transport the sediment far is very expensive and is not economically expedient. It cannot be thrown into the sea because it damages the sea environment, an impact which has been demonstrated by experiments (Bertman ***et al,*** 1983; Shuisky ***et al,*** 1989). For this reasons a new idea was tabled: what if we use these masses of sediment to protect the sea shore near the western port jetty? The idea was realized. Corresponding technology, in which masses of depositions were distributed at the bottom of quickly retreating abrasive cliffs to provide a kind of terrace, was worked out. The length of the terrace was greater than 1,100 m, the width averaged 180 m, and the average thickness was about 7 m. The area of the terrace surface was about 200,000 m^2. Creation of a large barrier of limestone fragments was started along its outer edge. While the work was being done, a considerable part of the terrace was eroded by waves. In a short time, about 5-7 m, was eroded but these eroded deposits were compensated for by new material so that the total dimensions of the artificial terrace, in general, remained unchanged. When the pouring of the limestone fragments to form the barrier was completed, rates of terrace erosion slowed considerably. Before this modification, and over a period of 2.5 years, the sea reworked nearly 900,000 m^3 of sediment of which almost 35% represented fractions coarser than 0.1 mm. This means that a rich artificial source of sediment had appeared, and it provided nearly 315,000 m^3 of beachforming materials. On the average, this amount equals the average long-term budget of beachforming drift in this area. Nevertheless, this rich injection did not lead to over-saturation of the local coastal zone since, in some years, the sum of nourishment sources provides up to 250,000 m^3/year of drift to the lithbdynamic cell. Nevertheless, a wide beach of up to 1,000 m long and up to 35 m wide with a specific quantity of drift averaging 51 m^3/m, appeared to the west of the western jetty and artificial terrace. This new beach protected a sliding cliff of about 1,000 m in length against abrasion. When sediment injections stopped in 1976, and the seaward edge of the artificial terrace became stable in 1979, a new beach westward of the terrace was the first to become eroded. Then abrasion processes grew more active up to Odessa Bay. As to the section where the new beach is situated, the rate of cliff retreat here is considerably lower than on the abrading shores of the lithodynamic cell on the whole, and was equal to only 0.2 m/year up to 1989. This is almost 5 times less than before the construction of portal jetties and 15 times less than during the period of active abrasion from the lee side of the jetties.

The seaward edge of the limestone-belted artificial terrace is quickly reworked by waves. Six years after terrace construction, the balance profile was formed and its sea slope became relatively stable on the whole. It adapted itself to local wave conditions, which is not possible in the case of concrete and metallic shore protecting constructions. This elastic property differentiates the terrace from more traditional constructions. Besides, during the process of profile balancing, almost 57,000 m^3 of sandy and pebbly drift appeared under the influence of wave reworking of limestone fragments. These drifts maintained the dimensions of the new beach westward of the port's jetties. No other shore protecting construction is able to serve as a source of drift for purposes of preserving traditional constructions (groins, moles, walls). And finally, in addition to the advantages mentioned above, the construction of the shore protecting terrace did not require important building materials such as concrete, metal and wood. The surface of this artificial form is used for the creation of recreational areas, lighted pavilions and parks. The connected beach is used for recreation and sea-bathing.

6. CONCLUSION

Subjects considered in this investigation allow a better understanding of problems connected with impact of port construction in untidal sea shore environments. In most cases, it is useful to consider natural conditions against the background of the development of a alongshore lithodynamic cell. Methods distinguishing the boundaries of the cell, and of drift balances within the cell, were worked out. As a result, it was possible to give a quantitative evaluation of the impact of port construction on morphological and lithodynamical processes in the coastal zone and therefore to predict this impact. Probably, this experience can be applied to the shores of tidal seas as well. To illustrate this an example (Yuzhniy port) in the coastal zone of the Black Sea between Odessa Bay and Adjiask Cape, has been described. It is important that the calculation of drift budget takes into account the tidal component of drift volume which is needed for determining the formulas. During the construction of Yuzhniy port, unusual shore protecting construction was created which helped to solve some difficult problems.

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