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POLISH COASTAL ZONE EROSION IN THE ASPECT OF NEED FOR COASTAL DEFENCE

Abstract

The balance of changes of the position of the coastline and of land area changes, made for the period 1875-1979, and of changes of the waterline and dune/cliff foot line for the period 1960-1983, has shown that in the last decades erosional processes are steadily increasing. At present 22% (110 km) of the Polish coastline is protected by structures. The growing rates of erosion, and the widening reach of damages, indicate that coastal protection works should be intensified and/or the hitherto used method should be verified.

1. Introduction

All engineering operations in the coastal zone depend on the scale of morpho- and lithodynamic erosional processes. Because of that the problem of determining the magnitude of coastline change has often been discussed [2, 7]. In the present work, to obtain data for the analysis of the trend of coastline development, cartographic materials covering the last 100 years were compared. Earlier, the same method was used by Hartnack [5] in his monography of the Pomeranian coast. Cartographic materials firom the periods 1875-1979 and 1960-1983 have supplied the first complete set of data characterising the rates of coastline change over such a long period and large area of the Polish coast. The data allowed a quantitative assessment of contemporary coastal processes. Prussian and Polish 1:25.000 topographic maps were the basic material, allowing to determine the changes in position of the coastline in the last 100 years. Cartometric measurements on these maps were made for the whole Polish coast except the Vistula Lagoon and Szczecin Lagoon [6]. Detailed evaluation of coastal changes in the period 1960-1983 was made using data from measurements on 1:2.500 plans of the technical belt [9] and on 1:2.500 topographical plans. Cartometric measurements on 1:25.000 maps were made every 500 m along 447 km of dune and cliff coastline.

2. Erosional/accretional elements of the coastal svstem

In the light of obtained results, the Polish coast is at present eroded along 74% of its length, and the sea is entering onto incresing areas of land. Rates of erosion vary. Erosion is accompanied by accretion, which allows partial reconstruction of coastal forms.

Basing on the cartometric measurements, graphs of differences in the position of the coastline have been developed for the 100-year period 1875-1979; for the 23-year period 1970-1983 and for the 13-year period 1971-1983 graphs of the differences in position of the waterline and dune/cliff foot line were developed. The differential line is of a semiwave character, with irregularly distributed stretches with opposing trends. The long term disrection of changes should be treated as the resultant of variable influences of waves, currents and sea level on which sediment transport depends. In areas with small resources of sediments, concentration of energy results in intense coastal erosion, and in result in the development of long stretches of erosion. Analysis of the length of stretches with varying rates of displacement of the waterline and dune/cliff foot line, and with changing land area, was the basis for distinguishing the following levels of the erosion/accretion system of the Southern Baltic coast. Erosional and accretional stretches of three length classes are the basic elements. To Class I belong stretches with length exceeding 4 km, in Class II are stretches 2-4 km long, in Class III - are stretches shorter than 2 km. Pairs of Class I and II stretches with opposing trends formed erosional/ accretional bistructures belonging to the higher level of the system. Still higher elements of the system's structure are lithodynamic units, morphodynamic regions and subsystems of the open sea and of the Gulf of Gdańsk and Pomeranian Bay [9].

3. Changes of coastline in the vears 1875-1983

The balance of rates of coastline displacement shows that during the last 100 years processes of erosion dominated along 61% of the Polish coastline, accretion prevailed over the remaining 39%. The average rate of erosion along Class I stretches, which covered 44.6% of the coastline, was -0.53 m/year (Fig. 1). Accretion in stretches of this class is evaluated at 0.59 m/year. The balance of changes of land area was -42 thous. m^2/year, and resulted from the greater by 85 km length of erosional stretches. Coastal processes during the last 100 years in stretches of all classes resulted in retreat ot the whole coastline at an average rate of -0.08 m/year, resulting in loss of 37 thous. m^2 of land area per year. The open sea coastline retreated at a rate of -0.12 m/vear, which value should be adopted as an indicator of coastal zone changes during the last 100 years.

The balance made for the period 1960-1983 showed that Class I stretches play a predominant role. Due to erosion in Class I stretches, which covered 216 km or coastline and which proceeded at an average rate of -0.94 m/year, 203 thous. m^2 of land area were lost every year. The rate of accretion along 37 km of Class I stretches was 0.3 m/year, resulting in increases of land area of 11 thous. m^2/year. In the period 1971-1983 the average rate of erosion in Class I stretches increased to -1.46 m/year (land area loss 314 thous. m^2 per year); only 5% of lost land area was reconstructed due to accretion in Class I stretches. Class II stretches were eroded in the period 1960-1983 at the rate of -0.97 m/year. The rate of accretion in stretches of this class was 0.76 m/year. In the period 1971- 1983 rates of erosion in Class II stretches more than doubled. In the period 1960-1983 the average rate of coastline retreat for all classes was -0.5 m/year, and in the 13-year period 1971-1983 it reached -0.93 m/year. Intensification of erosion showed not only in increased rates of retreat but also in extended spatial reach of erosion. The percentage of destroyed beaches grew, and smaller dune and beach areas were reproduced.

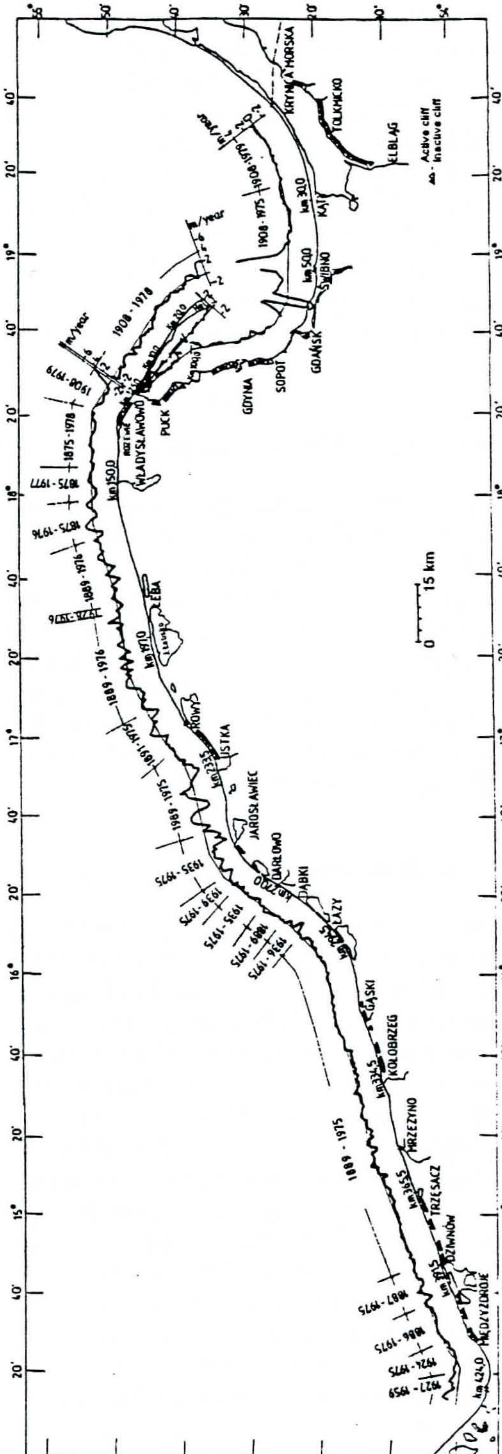

Fig. 1. Changes of coastline position (m/year) for 1875-1979

Accretion, which accompanied the processes of erosion, caused that in the 100-year period 69% of the destroyed land area was reproduced. Due to sea level rise and to smaller amounts of migrating sediments, in the period 1960-1983 20%, and in 1971-1983 only 14% of land area was reproduced. Erosion increased in stretches of all classes, within lithodynamic units of the open sea and Gulf of Gdańsk and Pomeranian Bay subsytems. The percentage of rebuilt land area reflects the appearance of transgressive erosion, connected with accelerated sea level rise. The average sea level rise along the Polish coastline during the last 100 years was 10.6 cm. The increasing during the last years number of significant storm surges [4] is one of the reasons for the quicker sea level rise than it would result from the eustatic change itself. Analysis points towards high statistical significance of correlation between mean coastline changes and relative sea level rise within most of the elements of the Southern Baltic coastal system.

4. Changes of the dune/cliff foot line in the period 1960-1983

The foot of dunes or cliffs undergoes changes mainly in effect of extreme storm surges. The amplitude of these changes is much smaller than in case of the waterline. The rate of dune/cliff foot displacement is an indicator of the real development of the coastal zone. In the period 1960-1983, along Class I stretches, dune and cliff foots retreated along 169 km of the coastline; accretion proceeded along 40 km (Fig. 2). Loss of dune and cliff area was about -57 thous. m^2/year. In the period 1971-1983 erosion in Class I reached rates of -0.99 m/year. Accretion occured along only 27 km of Class I stretches, and did not counterbalance the erosion. Loss of dune and cliff area was -152 thous. m^2/year. The mean value of dune and cliff foot retreat along stretches of all classes in the period 1960-1983 was -0.16 m/year, and in the years 1971-1983 it increased to -0.35 m/year.

5. Hydrotechnical coastal protection

Various types of hydrotechnical coastal protection structures are present along 20% of the Polish coastline. About 87 km of the coast is under the influence of groynes, ca. 30 km are protected by light and heaw revetments. The Hel Peninsula is hydrotechnically protected along 34% of its length. Especially high development of coastal protection structures is in two morphodynamic regions within the Jarosławiec-Sarbinowo-Świnoujście part of the Polish coastline - coastal defence structures are built along 71km of the 126 km long coastline. The first structures were built in the region of Jarosławiec, by the ports of Darłówko and Kołobrzeg, and at the cliff at Niechorze. Along these stretches, coastal defence systems were constantly developed up to present since mid XIXth century [1], which indicates that they were especially endangered bv marine erosion. The eroded cliff coasts and low land east of the ports were protected due to the risk of sliding or flooding. Local coastal erosion was induced by the development of the small ports of the western coast, and by the contemporarv transgression of the nea. Since the beginning of this century, until the 40ties, mainly groynes were used; also some light and heavy revetments were built. In the years 1946-1980 groyne systems were built along 87 km, light revetments along 12 km and heavy revetments along about 7 km ot the coastline. After it was observed that groynes and revetments become less etnective, these methods of coastal protection are much less used. At the end of the 70ties artificial nourishment (in the shallow water zone) was introduced. This method has been used with good effect along the Hel Peninsula.

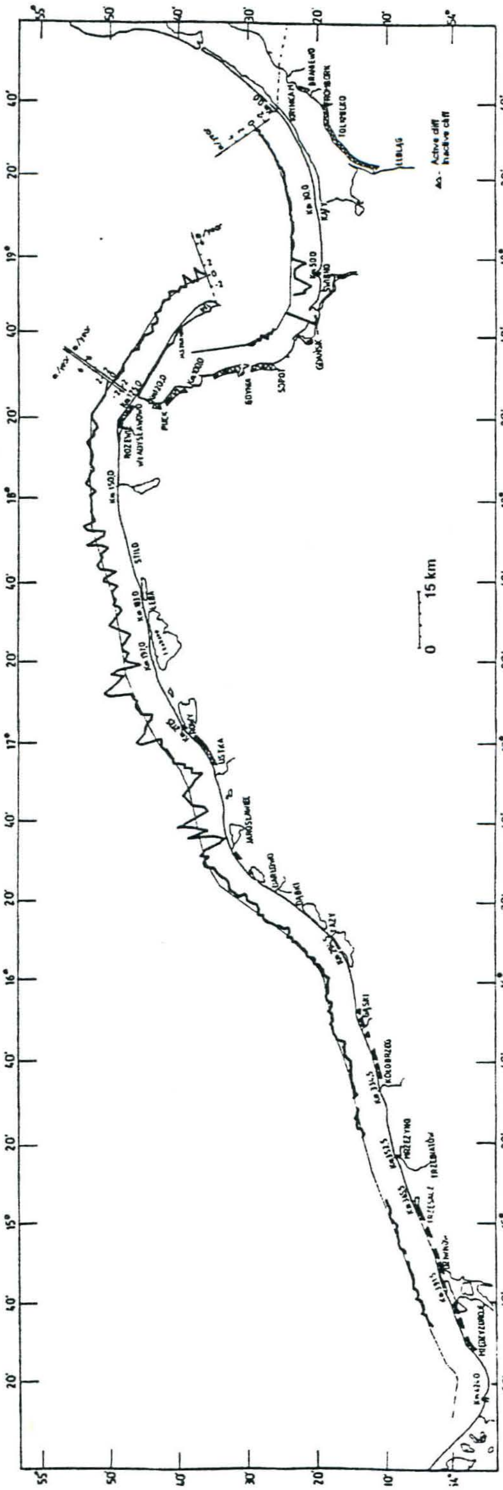

Fig. 2. Changes of dune/cliff foot position (m/year) for 1960-1983

Due to the influence of existing coastal defence systems on neighbouring coasts, these systems have to be extended still further along the shore, or the next lines of defence must be built (revetments, seawalls, rubble mounds, artificial nourishment in already protected areas). The necessity of further development of coastal defence systems in regions located very far apart may even suggest the influence of some superior factor - probably the sea level rise in the Baltic [3].

Analysis of the rhythm of changes of coastal forms during the last decades allows to distinguish many segments of the coast, along which this rhythm is disappearing - both on the waterline and the dune/cliff foot line. This reflects the influence of port breakwaters and of growing groyne systems along nearport, cliff and spit segments of the coast. These structures changed the natural course of lithodynamic processes, and stabilised a new spatial structure of the morpho- and lithodynamic systems along significant lengths of the coastline. As a result, new coastal defence works became necessary along the same stretches. Sea level rise is the next important cause of increased erosion, which locally reaches the level of coastal disaster - especially along stretches with a thin littoral cover. The irifluence of both the above factors has increased the sediment deficit, which is especially visible in nearport areas. Very large coastal disturbances developed in the area of influence of the port at Kołobrzeg. The first groynes were built there in 1874-1875. In the 100-year period 1875-1979 erosion only - with no intermediate accretional stretches - appeared along a stretch 12 km long, in the period 1960-1983 it was 25 km long, and in the period 1971-1983 erosion covered 47 km of the coastline directly east of the port. Disturbed lithodynamic equilibrium near the port at Darlowo (built in the years 1874-1883) caused that in the first phase a 3 km long erosional bay appeared, which developed to 15 km in the period 1960-1983. Coastal changes in the vicinity of other ports developed in a similar way. Attempts at stopping or slowing down erosional changes in nearport areas by building coastal defence systems, after a short term of stabilisation or even accretion, resulted in lengthening of the parts of coastline with disturbed natural processes. The initially short erosional bays, which were filled up with groynes and revetments, relatively quickly developed eastwards of the two ports at an average rate of 0.15 km/year. Evaluation of the coastal changes in the period 1875-1979 within groyne systems downstream of ports, showed a 4 times higher rate of retreat (-0.36 m/year) than the overall mean rate for the 100-year period. Within groyne systems not connected with port-induced erosion, the rate of retreat was 2.5 times higher (-0.21 m/year) than the 100-year mean.

6. Conclusions

From the programs of coastal defence/protection contained in reports on the state ot the Polish coastal zone [2, 10] results that at least 30% of the Polish open sea and Gulf of Gdańsk coastline requires protection works. Analysis of changes during the last 100 years and during recent shorter periods shows that protection of only spits and cliffs, along which the average rate of retreat in the period 1971-1983 was abt. -1 m/year, would cover 20% of the coastline. If the option of full protection of all stretches eroded at a rate of -1.5 m/year was adopted, then 70% of the Polish coastline would have to be protected. Assuming that the change of dune/cliff foot position reflects better than the waterline position the trend of coastal development [8], coastal defence/protection systems should exist along most of the stretches where dune foot retreat exceeds -1 m/year. Such stretches are present along 62% of the analysed coastline.

The development, and partial fixing, of the seminatural rhythm of coastal form variability (of anthropogenic origin) within the natural coastal system, points out that used up to this time methods of coastal protection require critical analysis and verification. This is especially important in the light of the predicted sea level changes. From the point of view of the conservation of the natural lithodynamic system, evaluation of changes of components of the coastal system should become an inseperable element of predesign works, preceeding all selections of protection options and engineering activities. However, even recently - as in the XIXth century - coastal defence works were undertaken without complex evaluations of coastal processes proceeding within at least the length of a morphodynamic region. Correct assessment of used up to this time coastal defence systems is rather difficult. However, presented data indicate that generally these systems introduced a disturbing irifluence into natural lithodynamic processes along a large part of the Southern Baltic coastal system. Presented results also indicate that in spite of the random character of the driving forces, the progress of coastal processes is deterministic, and therefore their modification in accordance with objectives designated by man is possible only to a very small degree.

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