THE RESULTS OF EXPERIMENTS IN THE AREA OF HIGHWAY EROSION

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ABSTRACT

Research of wave regime and transformation of waterside relief in the coastal area of intense destruction of the road Yuzhno-Sakhalinsk – Okha, started in 2007, was continued in 2012–2013. Three detailed bottom bathymetric surveys were conducted, one of which showed a significant relief change. Comparison of the results of regular surveys and analysis of synoptic situation led to the conclusion that the most noticeable changes occur in autumn and winter periods, when the energy of cyclones attains maximum level, and it must be considered to ensure the safety of traffic on the Trans-Sakhalin road.

ENGLISH SUMMARY

Background.

In previous articles on the declared subject [5, 9], the authors analyzed the data and bathymetric surveys of sea waves, received by the Institute of Marine Geology and Geophysics of Far-Eastern Branch of Russian Academy of sciences in 2009–2011 during full-scale experiments in the south- east of the island in the area of 104–109 km where the places of stream bank erosion and destruction of the Trans-Sakhalin road Yuzhno-Sakhalinsk – Okha are located. It was found that infragravity waves constituted the main cause of the destruction [6,8]. Those waves resulted from the transformation of wind waves and swell in the shallow water, due to modal structures of which appear underflow currents. They, in turn, lead to the formation of quasi-rhythmic structures in the form of cells, in which the drift is found, and at their external borders – accumulation zones in the form of crescent shape bars.

For the present water area the analysis of the energy spectra of sea level fluctuations (heaving) in the range of infragravity waves, recorded with the use of autonomous heaving recorders ARV ARV-11 and 12, showed that when storms approached, the energy of infragravity waves increases two, and sometimes three time as compared with calm weather.

In addition, processing of bathymetric surveys data made it possible to discover quasi-rhythmic structure – festoons, extended in chains in the longshore direction with characteristic dimensions of a part 500–700 200 m. At the survey area with total length of about 4.0 km seven such cells are clearly identified. North of the marked section, such structures are not found, to the south similar structures are smaller in size and depth, gradually leveling to the south. As it was shown in [7,8], this is due, apparently, to the fact that the formation of stable infragravity edge waves requires specific conditions – the period swell diffracted wave must match the resonance at a certain angle of approach. Therefore, the presence of large festoons on the beach and their extensions on the adjacent beach was observed only in some areas of the Sakhalin coast.

Since the analysis of bathymetric data did not give a clear picture of the motion of the local zones of erosion and drift accumulation, bathymetric surveys were continued in the subsequent 2012–2013 and gave the opportunity to obtain additional material on observations, which allowed making more definite conclusions.

Methods.

First, the authors analyze synoptic situation over the Sea of Okhotsk. As it was shown in [7,8], infragravity waves, whose intensity increases significantly during heavy storms, contribute to the destruction of the coast.

Meteorological processes over the Sea of Okhotsk have well-marked monsoon character due to contrasts in the heating and cooling of the continent and the ocean.

Analysis of the meteorological conditions for the Sea of Okhotsk, and in particular, the area of the road erosion according to the data of Russian Hydrometeorological Services shows that stormy winds caused by cyclones, and the considerable length of fetch [2,4] contribute to the development of storm wave. Maximum wind speeds in the Sakhalin area are observed in November and December, when possible wind gusts are up to 30–40 m / s [3, 4]. Direction of the stormy wind in the central part of the sea depends on the location of the cyclone center, and since its position changes, the wind direction is not stable. In the studied area during the cold season the predominant direction of the stormy wind is northward, northeastward, northwestward when deep cyclone moves over the south of the island from the south- west to north- east, and in the warm season winds have alternating directions.

Waves with height of 4 m are observed each month, their frequency is 15–20%, and 8 m high in autumn from September to November, when the waters of the sea are ice-free and frequent storms contribute to the development of storm wave. Repeatability of such waves is 1–1.5%. Waves with height of 10 m and more appear in the Sea of Okhotsk extremely rare. The most severe storms occur in its southern part in the period from January to May when cyclones are formed over the waters of the Southern Seas and the northwestern part of the Pacific Ocean. [4] With this type of meteoprocesses, waves with height of 6–8 m are observed in January 6–8 m, and up to 10 m in September-December.

The full-scale data obtained in the experiments demonstrated two cases of significant destruction of the coast with damage to federal road bed that occurred in 2009–2010 and 2012–2013. Both cases relate to the autumn-winter period and in future a repetition of such situations with the destruction of the coast during this period should be expected.

Then the authors of the article turn to the issues of bottom relief transformation. Bathymetric surveys in the area of 104–109 km of TransSakhalin road Yuzhno-Sakhalinsk – Okha were held regularly at intervals of about six months from October 2009 to July 2013. Scientists had a boat «Yamaha» with a chart plotter – echo sounder Lawrence XDS-5. Echo- sounding profiles were performed perpendicular to the coast in 200 m, on the removal of up to 2.0 km. Echo- sounder data were processed by a special program developed by Philip A. Plekhanov, and based on these data bathymetric maps and maps of the relief difference were created, showing the change in depth compared to previous measurements.

Often the difference between the two soundings (bathymetric maps), which were made six months later, and especially in spring and summer, was small, and it was impossible to determine the direction of festoons displacement and *moving of bottom relief. Until 2013, only one case showed significant differences (Pic. 1a), when bathymetric maps of autumn of 2009 and spring of 2010 years were compared. It was only in 2013 when similar results again change of bottom relief changes were obtained again, when bathymetry of autumn-spring was compared (Pic. 1b).*

Bathymetric maps of 2010 and 2013 highlight seven well-defined structures as quasi-rhythmic structures in the form of cells formed by convex seaward wave on one hand and concavity of the shore on the other hand. Formation of the marked structures is consistent with the existing notions about the impact of edge waves on the formation of coastal relief [7, 8].

Maps (Pic. 1), reflecting bottom relief changes in the periods of surveys 2009–2010 and 2012–2013, corresponding lithodynamic processes in autumn and winter, show in the coastal zone clearly visible redistribution of coastal drift: in the first and second cases, there was a displacement of drift of festoon wave back in great depth, and areas of the wave adjacent to the coast, characterized by an increase in the steepness of slopes due to the washout of the sole and accumulation on the back.

It is also noticeable that drifts near the coast tend to erosion. Pulling the wave back in the deep zone occurs due to a strong storm wave during the cold period with higher waves; during storms drifts tend to move from the coast towards the sea, in addition, the depth over wave back is closely and directly related to the wave height [4].

It should be noted that changes in bottom relief during the summer period are small, though rhythmic structures in the coastal zone also appear, but to a much lesser extent than in the previously considered cases.

In addition, bathymetric surveys in 2013 allowed confirming earlier assumptions that the conditions for formation of stable edge waves are rather rigid and therefore forms longshore displacement of quasi-rhythnic forms does not occur and intensive lithodynamic processes can be observed, as a rule, in the autumn-winter period in the years of active cyclogenesis.

Conclusions.

Analysis of weather conditions over the Sea of Okhotsk and the area of the road erosion according to the data of Russian Hydrometeorological Services indicates that maximum wind speeds in the Sakhalin area are observed in November and December, with the active cyclogenesis and contribute to storm wave at sea. This should be considered to ensure the safety of traffic on the Trans-Sakhalin road Yuzhno-Sakhalinsk-Okha.

Comparison of bottom relief on the results of bathymetric surveys carried out from October 2009 to July 2013, showed the formation of alternating zones of erosion and drift accumulation in the form of a series of crescent-shape bars in the studied seaside area in winter, due to the cyclonic activity in this season. At the same time intense redistribution of drifts in the coastal zone did not occur every season, and only during periods of 2009–2010 and 2012–2013, when there were the most powerful cyclones.

Long-term bathymetric surveys for four years with a periodicity of six months allowed confirming that earlier assumptions about the harsh conditions of the formation of stable edge waves are justified, and therefore there is a reason to believe: a significant longshore displacement of quasi-rhythmic forms does not occur.

Keywords: *highway, erosion area, field studies, bathymetric surveys, comparative analysis.*

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