Technology of road construction and laying of pipelines in marshy and waterlogged areas using pontoon modules

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Abstract. The development of environmentally friendly technology for the construction of non-rigid roads and systems for laying pipelines on block elements from composite pontoon modules in swampy and waterlogged areas for the Far North and Siberia is presented.

1. Introduction
A characteristic feature of the development of hydrocarbon resources in the vast swampy and waterlogged areas of Western Siberia and especially the Far North is the consideration and interaction of the environment with the pipeline system, long-distance and line service roads.

Problems arise at the first stage of route selection: how to connect points A and B, where the route will pass, what obstacles it will cross, how to assess the most hard-to-pass sections of the route, how to link the route with existing and planned future pipeline systems, existing and planned auto and railways, how to link them together, etc. [1]

It is known that in conditions of high swampiness, the creation and maintenance of line service roads on the territory of Western Siberia, including the regions of the Far North, in operating condition requires enormous costs.

The studies conducted by the authors in the field, as well as the analysis of the results of space diagnostics of the territories of Western Siberia and the Far North, showed that more than 48% of the territory is covered by type 3 swamps, 23% by water crossings, and the rest by permafrost soils with deep seasonal freezing (>3.0m) [5].

2. Problem description
Under these conditions, when searching for the optimal route of pipelines and line service roads while avoiding the above obstacles, the route lengths are overestimated by 43%, thereby creating complex configurations of the oil and gas pipeline network, which in turn additionally factorially increases the failure of the entire system. Based on the studies of failure diagnostics in the main oil and gas pipelines of Western Siberia and the Far North, diagrams are constructed where these situations are clearly shown (Figure 1).
Analysis of the distribution of failures at the main oil and gas pipelines showed that the number of accidents of the linear part largely depends on the degree of swampiness of the territory, on water crossings and configuration.

Therefore, when laying pipelines with low bearing capacity of type 3 swamps underground, in waterlogged areas, permafrost soils and in soils with deep seasonal freezing, significant movements of pipelines occur, with a loss of longitudinal stability and their emergence to the surface, with the formation of arches and their configuration (Figure 2).

All this changes the stress state of the pipelines and leads to an overstatement of stresses by 3–4 times relative to the normative ones [2, 8]. These system parameters make it necessary to adjust the design schemes and strength calculations to determine the stress-strain state and select appropriate materials, due to loads and impacts based on the limit ones.

In the process of heavy traffic of heavy construction equipment and vehicles along temporary line service roads with elevated soil moisture, sharp daily temperature fluctuations (up to 30°), various types of deep gauges (internal, external, deep, surface) appear. At the same time, the layers of pavement, subgrade, roads become unstable, since their physicochemical properties do not meet the requirements for shear resistance, strength and other indicators that change during the operation of line service roads and the pipeline itself [4, 10]. This leads to the fact that the equipment is drowning, falling through,
getting stuck in a swamp and often remains there forever, which leads to significant economic and environmental costs (Figure 3).

Figure 3. Work of excavators in the winter and summer periods on swampy and waterlogged areas

According to our proposal, for the first time in the design of the pipeline and line service roads of a new type, the above-mentioned shortcomings can be reduced or completely eliminated.

To this end, in order to create reliable and long-term integrated road structures and oil and gas pipelines, a fundamentally new method for the construction and operation of pipeline systems is proposed. This method will greatly complement traditional construction methods with new progressive technological properties.

3. Materials and methods
The essence of the method is as follows. A profile of a complex structure constructed from composite materials (pontoons for bedding) shown in Figure 4 with rutting guides will provide increased reliability of the line service road, buoyancy, smooth running of a self-propelled lifting and loading equipment designed as a “centipede”, which has a number of significant advantages in the construction and operation of the entire complex, as shown in Figure 5.
On the pontoons, made in the form of a module of composite materials and having inside the power frame assembled in the form of a guy, two rutting guides of the channel type are mounted, facing the shelves up. The gauge is so large that construction and repair equipment (the “centipede” pipe-laying machine) and automobile transport can pass along these guides. The number of modules is determined on the basis of the bearing capacity of the module itself and the load that will be applied to the pontoon base (constant load from the mass of the pipeline and temporary load from the mass of the automated pipe layer during the construction, repair, and maintenance of the pipeline).

Pontoons in the longitudinal and transverse directions are fastened together by composite cables. Longitudinal cables are fixed at fixed distances in the land part with “anchors” installed in wells or small buildings, with hydraulic lifts to maintain a constant level of the road and pipeline in the pontoon system [6, 9].

The cables passing along the side and bottom of the pontoons enter the well through special holes and are wound onto the drums using an engine with a gearbox (Figures 6 and 7).
Figure 7. General view of a technological well with cables

The technological well is delivered to the route in the form of a one-piece, fully equipped unit of modular type. When installing the technological well unit (TWU), it is necessary to ensure the integrity of the structure, to prevent water, dirt, etc. from getting inside the unit.

In parallel with the installation of the TWU in the design position, anchors must be installed. Shot anchors, which can be buried in the underlying soil up to 5 m, regardless of the thickness of the peat layer, were adopted as anchors. The anchors are immersed in the ground with the help of special installations on caterpillar tracks with the increased off-road performance [7, 11].

The following is an example of a completed project for the construction of a pontoon-type roadbed made of modules using a “centipede” connected in the form of a continuous guy for driving equipment and laying the pipeline, as shown in Figure 8 a, b, c, d.

Figure 8. Construction of a roadbed from composite pontoon modules: a - laying a cable through an obstacle using a ground-effect vehicle, b - cable fastening in a well, c - laying the pontoon module on cables, d - fixing the pontoon module on cables.
On the pontoons, made in the form of a module of composite materials and having inside the power frame assembled in the form of a guy, two rutting guides of the channel type are mounted, facing the shelves up. The gauge is so large that construction and repair equipment (the "centipede" pipe-laying machine) and, if necessary, automobile transport can pass along these guides. [12,13].

As you can see, this system completely eliminates the use of automated pipe layers and excavators for digging trenches.

All this creates the conditions for a new technology of laying roads from new structural materials and pipelines on bedding elements by the ground method, tangible savings in fuel and resources when laying such a pipeline route and almost eliminates overburden work. The profile of the earth's surface, due to the peculiarities of the formation of the relief by natural influences, is much closer to curves with a variable radius, which gives the best fit of such a route into the terrain [14,15].

4. Conclusion
An analysis of the research work carried out in recent years on the adoption of an innovative concept for the design, construction and operation of roads using new technological systems, as well as maintenance and repair of pipelines, indicates the complexity of the problem, the optimal solution of which is possible only with the use of complex mathematical methods for design analysis, modern materials, computer technology for managing innovative transport systems working on alternative types of energy. It should be noted that some tasks were solved at a sufficient scientific level and currently have high scientific and practical value.

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