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Executive Summary Of Innovative Transport Technology "String Transport Unitsky"

1. Introduction

Analysis of transport state-of-the-art and its perspectives was carried out as the part of the Transport Strategy of Russian Federation till 2030. It proves that there are a number of limitations for transport development in Russia. Among them one can mention high rate of capital and energy output, severe climatic conditions, long period of project implementation, low transport infrastructure payback.

In such conditions formation of competitive transport services market is impossible without progressive achievements of techniques and technologies which are in conform to the security standards. The most important development direction becomes the implementation of innovative technologies in transport sphere. Therefore, introduction of Unitsky String Transport (STU) may become one of the most perspective directions in innovative transport technologies development. In November, 2008 Transport Committee of State Duma of the Federal Assembly of the Russian Federation admitted STU to be the best innovative project in terms of Consultative Council "Transport unites Russia" on project "Innovative Types of XXI Century Transportation in Russia". STU was also recommended for early implementation to the economic scheme of the country.

String transport is the transport of "the second level". Its infrastructure doesn't need great deal of land resources. STU has spans (from 30-50m to 1-2km) between supports which provide STU passing through swampy, sand and mountain terrain, water barriers, boreal forest, cold desert and above ever frozen ground. STU has large energy efficiency and is less capital-intensive in comparison with monorail, elevated roads with magnetic levitation trains or high speed railways. STU is resistant enough to atmospheric effects, earthquakes, floods and other natural disasters. STU system meets Russian standards SNiP (Construction Standards and Regulations) and GOST (all-Union State Standard), has Russian and international patents. Basic compounds and details of the system have been tested and are certified in accordance with

Russian legislation. Above mentioned advantages allow to introduce a new type of transport in a small period of time. It will solve public, suburban and intercity transportation problems and also the problem of passenger and transportation overload.

2. String Transport Concept

String transport consists of several supports located at a distance one from another, string-rails tensed on them and self-moving vehicles called unibuses. The main difference between STU and conventional railway is that string-rails are raised above the terrain 3 and even more meters high, they are strained between supports and are pretensioned up to 100-500 tons efforts and even more. It provides high stiffness of a string-rail track which is determined from relation of span structure deflection to the length of a span (about 1/1000). At the same time, there is no necessity of making subgrades, building crossovers, viaducts, bridges, pipe-culverts and other constructions. It results in high economic effectiveness of STU and its rapid building-up.

The string itself is a metallic box with pretensioned ropes inside of it. The ropes are made of 3-5mm diameter wires encapsulated with modified concrete or other filling on the basis of epoxide resin. The metallic box is covered with rail top where unibus wheeling takes place. Such string-rail construction provides not only protection against corrosion of load-bearing steel wires, but also high reliability of system functioning, because rail excursion on a span doesn't exceed ±15mm (towards midline) at low speeds and ±5mm at high unibus speed. Oscillation decay time is about 0.1 sec. Eventual uprise of resonant effects in a string-rail is compensated by choosing of reasonable unibus speed rate (low-, average-, high- and extra high speed string versions were designed). Eventual uprise of resonant effects in a string-rail may also be compensated by the rate of string-rail bending stiffness, string tension force and physical-mechanical specifications of a filling.

In comparison with conventional vehicles unibus is more cost-efficient due to its distinctive aerodynamic features. At speed rates over 200 km/h on a string railway unibus air resistance coefficient may be reduced to 0.1and lower because of screen effect elimination and due to patented highly aerodynamic mold lines.

STU transport system has different speed rate versions: up to 50km/h, up to 100 km/h, up to 150 km/h, up to 200 km/h, up to 300 km/h, up to 400 km/h, up to 500 km/h.

3. Short List of Work Performed

Since "String Transport Unitsky" Ltd was founded (1988) a large scope of scientific, experimental and development work has been implemented. It includes the following results classified in accordance with the abovementioned STU concept.

3.1 Supports

-Basic types of supports (anchor and intermediate) were designed; their configuration (mainly T-frame and П-frame) was determined for suspended and mounted STU.

-Optimum distances between anchor (up to 10km) and intermediate (30-50m for mounted and 100-300m for suspended STU) supports were determined. Besides, supports height (not less than 3m), depth of support setting (1.5-2.5m and more for panel-wall foundation and 6-8m and more for pile foundation, depending on physical-mechanical ground features and the depth of frost penetration) and support setting technology were determined.

-The types of support foundation were determined.

-The types of support malfunctions and their admissible values were determined.

-Admissible support leans were determined.

-Concrete grades necessary for building of supports and string-rail filling were determined in accordance with GOST 18105-86.

Building of supports and string-rail transport system of "the second level" is supposed to be implemented in accordance with Russian standard SNiP 2.05.03-84* "Bridges and pipes". Thus, string-rail constructions of a double-line track will be less resource-demanding, because there is no need of making continuous rail coverage.

3.2 String-Rail

-The shape of string-rail frame and its inner structure were determined for suspended and mounted STU in all versions (extralight, light, average, heavy and extraheavy).

-Strength properties of string steel ropes were determined in accordance with SNiP 2.05.03-84* "Bridges and pipes". Strings and frame bonding technique was also determined.

-The project principle is "the higher unibus speed is the stiffer a track should be and the more pretension in a string should be". In accordance with this principle string pretension values were determined (10-20 tons for extralight suspended track and 500-1000 tons and even more for extraheavy mounted string-rail track) depending on span length, gauge size, dynamical load mass and unibus speed rate.

-Safety coefficients of constantly and variably loaded tracks were determined.

-String weight per running meter was determined for different string-rail versions.

-The diagrams of static and dynamic string-rail deflections, caused by total weight of a track and a rolling stock taking into account different speed rates, were determined.

-Specific and absolute values of track irregularities on different spans of a track at different temperature rates were determined. For example, for high-speed STU (speed rate of 180km/h) maximum irregularity on 30m span will be 18mm (1/1667) at a specified temperature of +55°C and minimum irregularity will be 4mm (1/7500) at a temperature of 0°C.

-To increase dynamic evenness of a track it was recommended to make bending (deflection) of a rail frame in horizontal position upgrade to the extent equal to an average dynamic value of span deformation depending on string-rail vertical forces. Seamless linkage of string-rails was accepted. The diagrams of track deformation in terms of extreme atmospheric temperature were developed.

- Estimate of "wheel-rail top" contact stresses was fulfilled. They are 4-6 times lower than contact stresses of conventional railroads due to another type of wheel and rail bearing. The coefficient of unibus wheel rolling resistance was determined; the diagrams were developed and string-rail assumed service life (up to 100 years) was determined.

-In accordance with string-rail bending stiffness the values of a track curve radius both static and dynamic were determined. They should be no less than 1000m at unibus speed of 100km/h, no less than 10000m at unibus speed of 350km/h, no less than 20000m at unibus speed of 500km/h.

3.3 Unibuses

- A number of design solutions were suggested. Among them the design of passenger unibuses of different passenger capacity and the design of freight unicars intended for various cargo transportation (bulk and liquid cargoes, raw wood, containers, etc.) on different string-rail tracks (double-line of different gauge size and suspended or mounted monorail type).

-To increase unibus resistance on string-rails wheels with two bearing ribs are equipped with additional derailment side rollers. Clearance has negative value of approx. 100mm. Resonant vibrations dampeners are provided.

-Unibus design is worked out. It is based on the best equipment of world manufacturers.

-Fuel (energy) consumption per 100 km was determined.

-Track and dynamic analyses of high-speed (up to 450 km/h) passenger unibuses (two-wheel and multiwheel in the shape of a train) with 1m, 1.25m, 1.5m gauge and also of city bus (1.5m gauge) and city suspended mono-unibus were carried out.

-Braking distance changing intervals at speed rates up to 450 km/h for unibuses of different weight and capacity were determined.

-1:5 scale unibus models of different versions were tested several times in aerodynamic tunnel in Krylov Central Research Institute (St. Petersburg). Thereby drag coefficient was below 0.1.
-The analysis of how the above mentioned coefficient influences technical and economic features of high speed unibuses was carried out.
-Calculation of costs of unibus prototypes production was made. Its potential manufacturer was chosen.
-Acting models of high speed mounted STU with track of 1.5m (1:20 scale), 2m (1:5 scale), city unibus with a track of 2m (1:10 scale) were produced and tested.

3.4 Optional Equipment and Associated Systems

-Various types of unibus control systems were suggested. It can be either manual, semiautomatic or automatic control systems.
-STU was suggested to be equipped with automatic control systems produced in Russia which are used, for example, in light metro. The system might also be equipped with automatic control system produced abroad, in particular, by THALES (France), the world leader in this branch. They are widely used in public and intercity railway transport systems.
-Unibus point work constructions were developed.
-Passenger stations and suspended and mounted STU depots were designed.
-Alternate arrangement of suspended and mounted unibuses on string-rails was analyzed.

3.5 Transportation Process Organization

-Unibus traffic time intervals were determined (20-30sec. in the city STU in rush hours and 3-5 min. and more in the intercity high speed STU.
-Arrangements of passenger evacuation in case of emergency are provided. They include transportation of out-of-order unibuse to the nearest station or to the depot, he use of a special recovery vehicle. In extremely critical situations passengers are supposed to come down with the help of ropes or rope ladders.
-Satellite navigation system and unmanned control of the unibus are stipulated.
-A complex system of designing dynamic STU with speed rates up to 500 km/h was developed. Its main principle stipulates motionless strings and supports while unibus moving. All static and dynamic analyses were carried out with the aid of Patran-Marc and Patran-Nastran programmes.
-Equipment operation demands and environmental safety demands were determined.
-Alternatives of STU location in different cities, regions and countries were considered. The strategy of "the second level" transport system foundation was developed for the Khanty-Mansijsk Autonomous District – Yugra. It envisages installing of 3km of city, intercity and freight tracks. Expectative social-economic effect of the strategy realization is estimated at RUB 1.2 trillion.

Taking into account the effect in the abovementioned region (GDP growth, road accidents loss reduction, fuel economy, mineral resources and stock economy, environmental improvement, etc.) on a nationwide scale the strategy realization effect is estimated at RUB 100 trillion.

3.6 String Transport Performance Evaluation

-Metal structures (100-250kg) and iron concrete (0.1-0.3m^3) consumption per installation of 1m of double-line string-rail track was determined.
-Comparative evaluation of metal structures and iron concrete consumption for the installation of a conventional railroad (400-800kg/m of metal structures and 0.5-0.8m^3/m of iron concrete) and monorail (1500-3000kg/m of metal structures and 0.5-1.5m^3/m of iron concrete) was fulfilled taking into account earthwork in the scope of 10-50m^3/m.
-Evaluation costs (USD 1-1.2mln) of 1km of high-speed mounted light STU (1.5m gauge) installation in conditions of northland were determined. As a comparison, costs of 1km of a

conventional railroad (USD 3-5mln) and of a high-speed railway (USD 50-60mln) were estimated.

-Prime cost of track building was determined for all STU versions (suspended and mounted, extralight, light, average, heavy and extraheavy) of different speed rates (up to 100km/h, 200 km/h, 300 km/h, 400 km/h, 500 km/h) taking into account different geographical conditions. Different STU versions were considered (with contact wire line or without it, with manual, semiautomatic or automatic control systems, etc). The same with all STU components: string-rail track of "the second level", rolling stock and "the second level" infrastructure.

-Land allocation (about 100m³) per 1km of a string-rail track was determined. In comparison highway or railroad land allocation (5ha/km) was estimated.

-Estimation of STS efficiency was made which is determined by:

-environmental friendliness. Emissions of harmful substances into the atmosphere correlate as 0.01 per 100 passenger kilometers in comparison with 0.1 for conventional automobile transport. Electromagnetic emission rate is lower than it is in a trolleybus.

-small energy consumption (0.2-03 liters of gasoline per 100 passenger kilometers in comparison with bus consumption (1.8-2.5 liters/passenger km), tram and trolleybus consumption (1.6-1.9 liters/passenger km, energy converted to fuel), monorail consumption (1.3-1.6 liters/passenger km, depending on a speed rate).

-fewer land resources are needed (150-200 times fewer in comparison with motor and railway transport).

-fewer resource consumption (at the same time, STU building is 3-4 times faster than it is needed for motor roads or railroads).

-lower expenses (2-3times lower in comparison with railway building, 10-15 an more times lower in comparison with high-speed railway building, 15-20 and more times lower in comparison with monorail building, 20-25 and more times lower in comparison with maglev train, 3-4 and more times lower in comparison with autobahn).

The possibility of STU realization was presented with the help of one of the possible freight versions in Ozyory-town near Moscow in 2001-2008.

4. STU analysis in comparison with other transport systems. The possibility of its practical realization in adverse climatic and geographical conditions of Russian Federation (in terms of the Khanty-Mansijsk Autonomous District – Yugra).

Any transport system consists of three basic components: a track, a rolling stock and supporting infrastructure. Cost estimate of a new transport system is a great challenge. Usually only track costs are mentioned, not very often infrastructure costs are mentioned, and hardly ever rolling stock costs are mentioned. Table 4.1 represents the costs of different transport systems (rolling stock costs are not included).

Table 4.1

Transport Systems Cost

Transport System	Description of a System	Project Location	Double-line System Cost per 1km, USD mln.	Referral Source
City STU*	City line, up to 100kmh	Khanty-Mansijsk	2.4	Project Designer STU Ltd.
Speed STU*	Intercity line, up to 300kmh	Khanty-Mansijsk-Surgut, 250 km	1.3	Project Designer STU Ltd.
PRT-Ultra	City automated system, up to 40kmh	Heathrow airport in London	9.4	Manufacturer www.atsltd/co.uk/prt/faq
LRT-Tram	City tram line, up to 60kmh	Portland, Oregon, USA, 13.4km	43	Texas Association for Public Transport Development http://lightrailnow.org

Transport System	Description of a System	Project Location	Double-line System Cost per 1km, USD mln.	Referral Source
BRT-Isolated bus line	Exclusive Bus Line, up to 80kmh	Jacksonville, USA, 54.4km	10.6	Jacksonville Transport Department www.jtaonthemove.com
Monorail	Automated city line, up to 60kmh	Las Vegas, USA, 6.3km	103	Developer-Operator www.lvmonorail.com
Speed railway*	Diesel trains, up to 200kmh	Wentworthville-Las Vegas, 6.3km	10	Consortium of Developer-Operators http://www.desertexpress.com/economics.php
High-speed railway*	Electrified, up to 300kmh	California, USA, 1200km	35.5	CA Department of High-Speed Railways www.cahighspeedrail.ca.gov
High-speed railway*	Electrified, up to 350kmh	Moscow-Nizhny Novgorod, 400km	31	www.nta-nn.ru
Railway*	Intended for ore transportation, up to 80kmh	The Chita Region, Naryn-Lugokan, 375km	5.7	www.rzd-partner.ru
Light metro	Overhead city metro, up to 80kmh	Butovo, Moscow	34	www.metro.molot.ru
Motor road*	Intercity line, up to 120kmh	Moscow-St.Petersburg, 650km	13.5	www.g2p.ru
High-speed railway	Overhead electrified , up to 320kmh	Taiwan, the north-the south, 345km	43.5	www.niizhb.ru

* The data given is based on pre-design offers. STU data was taken from reports on contracts №7y and №12y concluded with the Khanty-Mansijsk Autonomous District – Yugra administrative authorities and performed in 2007.

Analysis of the data represented in Tab. 4.1 proves that STU is 10-20 times cheaper than other transport systems (including "the second level" systems on elevated structures).

Table 4.2 represents energy intensity of different transport systems in terms of crude energy (for electric systems in terms of thermal power stations fuel consumption taking into account energy loss in electric lines and other losses).

Table 4.2

Transport Systems Energy Intensity

Transport Facility	Fuel Consumption liters/100pass.km	Derived Energy Consumption Watt/pass.km	Efficiency of Crude Energy to Derived Energy Conversion, pct	Crude Energy Consumption Watt/pass.km
Electric unibus of city double-line mounted STU (12 passengers)	-	5.9	33.5	18
Electric unibus of city mono-rail suspended STU (12 passengers)	-	2.1	33	6.3
Electric unibus of speed intercity STU (200kmh, 11 passengers)	-	19.9	33.5	59

Transport Facility	Fuel Consumption liters/100pass.km	Derived Energy Consumption Watt/pass.km	Efficiency of Crude Energy to Derived Energy Conversion, pct	Crude Energy Consumption Watt/pass.km
Motor car (on average 1.7 passengers, 100kmh)	5.35	178	90.5	197
Bus (on average 80 pct of occupied seats, 60kmh)	0.71	23.7	90.5	26.2
Airplane (on average 70 pct of occupied seats, 900kmh)	5.30	177	92.0	192
Express train, 10 wagons (160kmh)	-	50	33.5	149
High-speed train, 14 wagons (250kmh)	-	61	33.5	182
High-speed maglev train Transrapid, 5 wagons (430 kmh)	-	176	31.0	568

The data, represented in Tab.4.2 (except for STU data), was taken from "Research on feasibility of high-speed railway with magnetic levitation train Berlin-Hamburg construction", VIEREGG-RÖSSLER GmbH Innovative Verkehrsberatung (the leading transport consulting company in Germany, http://www.vr-transport.de/transrapid.de/transrapid-energy/n003.html).

The analysis of the data, represented in Tab.4.2, proves that STU is the most cost-effective transport system. For example, in comparison with an airplane, intercity high-speed electric STU will be 3.3 times more cost-effective and non-electric diesel-drive STU will be $3.3\times90.5\%/33.5\%=8.9$ times more cost-efficient. In comparison with a high-speed rail, STU will be 2.5-3.1 times more cost-efficient. And in comparison with "Transrapid" maglev train, which is more energy-consuming than an airplane is, STU is 9.6 times more cost-efficient. City mounted STU, due to lower speed rates, will be approx. 3.3 times more efficient in comparison with intercity speed STU. Crude energy consumption of the city suspended STU will be 29 times even lower. And in comparison with a motor-car, STU energy consumption will be 31 times lower.

Taking all this data into account, STU is supposed to be the most environment friendly transport system ever known.

Due to string-rail specific characteristics, stated by a system designer, STU is less resource-demanding, more reliable and has longer service life than any other transport system.

Taking into account technical and economic benefits of the system, STU can also be exploited in the northlands and at river crossings (with the help of string highway and railroad bridges and crossings). Thus, the territories will be provided with up-to-date communications. At the present time "the second level" transport system produced on the basis of string technologies is supposed to be implemented in the Khanty-Mansijsk Autonomous District – Yugra. The necessity of making high-speed, economic, environmental friendly, long lasting and safe tracks, which meet the demands of the XXI century, in this region is clear enough. The Khanty-Mansijsk Autonomous District – Yugra is the most effective region of the Russian Federation, and its total area exceeds the territories of the majority of European countries. The project implementation is entirely possible and will depend on administrative and financial possibilities of region authorities. In the future STU might be developed and integrated into the transport infrastructure of the Russian Federation. The usage of radically new transport technologies will improve investment climate in any region of the Russian Federation. It will also move a base to solving of main social-economic problems.

5. STU Designing, Certification and Technical (Technological) Realizability

STU consists of three self-contained parts, which are separately designed and certified:
-rolling stock;
-"the second level" track and supports;
-"the second level" infrastructure.

5.1 Rolling Stock

Introduced by the project designer STU transport system refers to railway transport and serves for city and intercity transportation of passengers and cargoes.

City transportation rolling stock is a self-moving tram-type wagon. In fact, it is the sort of a conventional tram wagon in accordance with GOST 8802-78. STU tram wagon has a passenger cabin and drive endtrucks. There are doors, seats, ventilation, heating and conditioning systems, glass fixing, handrails and lighting in a passenger cabin. Endtrucks have electric drive, reduction gear and undercarriage equipped with brakes and mounting. The abovementioned compounds of a conventional tram wagon are mass produced by a number of Russian companies and by many foreign companies. These compounds might be in use for unibus construction or might be adapted to it. It follows that unibus might be developed and realized from technical point of view.

Intercity transportation rolling stock (a rail car) is a version of a motor car (passenger car, truck, minibus, bus, etc.), which is mounted on steel wheels.

The designed construction of a rail car (except for undercarriage) consists of the same compounds as a conventional motor car. There is a body, the doors, system motor, seats, cabin ventilation, heating and conditioning systems, glass fixing, handrails and lighting in a rail car. All the abovementioned compounds are also mass produced by many Russian and well-known foreign companies. These compounds might be in use for unibus construction or might be adapted to it.

Thus, self-moving city wagon is supposed to be equipped with the following certificated equipment produced by the leading foreign manufacturers of electric railway compounds:

-VEM Sachsenwerk GmbH, Germany (drive motors);
-L-3 Communications Magnet-Motor GmbH, USA-Germany (electric drive);
-Knorr-Bremse, Germany (brake system);
-VosslohKiepe GmbH, Germany (traction invertors);
-Bonatrans a.S. Bohumin, Czech Republic (undercarriage compounds);
-Gummi-Metall-Technik GmbH, Germany (undercarriage rubber-metal details);
-Webasto, Germany (conditioning system);
-Hübner, Germany (doors with opening device).

The production of these companies is supplied with the certificates, where equipment conformance to the requirements is stated.

The use of the certificated equipment, aggregates, details and system compounds, produced by well-known companies, will help the project designer to shorten rolling stock development time and will provide its high quality and reliability. It follows that unibuses and unicars might be developed and realized from technical point of view.

Rolling stock design and engineering is implemented in accordance with international requirements (UNECE, EN Standards, etc) and CIS regulations (GOSTs, OSTs, etc.) in the sphere of transport engineering. STU is supposed to make use of the following regulations:

-ambient noise level in accordance with UNECE Standard #51;
-electromagnetic compatibility in accordance with UNECE Standard #10;
-brake system requirements in accordance with GOST 8802-78 and EN Standard 13452-1;
-construction refractory features in accordance with UNECE Standard #52 and NPB Standard 20-2000;

-protective properties of a passenger cabin in accordance with UNECE Standard #29;

-interior layout of a passenger cabin concerning service and emergency doors accessibility, gangway dimensions, passenger seats size, seat pitch, the dimensions and construction of service and emergency doors, fire extinguishers equipment and hand-rail construction in accordance with UNECE Standard #36 and #52;

-in-cab noise level in accordance with GOST P 51616-2000;

-in-cab content of harmful substances in accordance with GOST P 51206-2004, GOST 12.1.005-88;

-radiointerference in accordance with GOST P 51318.12-99;

-heating, ventilation and conditioning in accordance with GOST P 50993-96;

-electrosafety in accordance with GOST 8802-78.

Meeting the requirements of transport engineering will help the project designer to ensure the rolling stock compliance with safety, reliability, ergonomics and environmental engineering demands.

To perform elaborating of normative documentation and certification of a rolling stock, the project designer has completed a cooperation arrangement with Science Research Institute of Electric Transport of Russian Federation (SRIET) in the sphere of city railway transport.

Thus, the project designer in cooperation with SRIET plans to fulfil the following scope of work:

-development of programs and techniques of rolling stock and its compounds stationary and running tests;

-organization of rolling stock prototype stationary and running tests and its certification;

-elaborating of rolling stock normative documentation;

The cooperation of the project designer with the Research Institute (SRIET) will help to shorten time needed for rolling stock certification.

The use of a certified equipment in rolling stock construction, fulfilling the requirements of Russian and international normative documentation in the sphere of transport engineering, cooperation with the Research Institute will help the project designer:

-to develop a rolling stock of high quality and in time;

-to provide a rolling stock with high safety, reliability, ergonomics and environmental protection standards;

-to shorten time needed for certification.

Taking into account the availability of facilities, technologies and equipment in Russia and in foreign countries, STU rolling stock might be developed and implemented in any climatic conditions of any region of Russian Federation including the Northlands.

5.2 Track Structure and Supports

STU string-rail track structure and supports are the variety of flying or cable-stayed bridges, because they represent trestle bridges. That is why making design documentation, the head engineering company follows bridge standards of Russian Federation SNiP 2.05.03-84* "Bridges and pipes". These standards cover railway, road and passenger bridges, subway and express tramway bridges, trestle bridges, pipe bridges and rail-road bridges.

STU Ltd has a conforming license № ГС-1-99-02-26-0-77045332-62-038379-1 "Designing of Buildings and Constructions of the I, II Importance Level in Accordance with the State Standard" including designing of high-speed transport lines and city electric transport, ropeways, bridges, high-rise buildings, etc. The license was issued to STU by the Russian Federal Agency for Construction, Housing Maintenance and Utilities on 02/05/2006. Besides, STU makes use of Russian standards in steel construction designing (SNiP II-23-81), some articles of European Standard (ENV) and new bridge standards of the USA (AASHTO). At the same time STU meets the most severe safety and durability requirements of all abovementioned standards.

Construction and building materials used in STU track structure designing are not unique. They consist of metals and alloy materials which are produced in a large scope by Russian and foreign manufacturers. They can be bought, they are certified, and there is no need of making extra expenses and performing technology development. Besides, there is no need in creation of manufacturing facilities and in certification of these materials.

Rail body and rail top are produced from already existing and manufactured according to GOST steel shapes (as a string rail top in some of its versions the designer suggests to make use of a conventional rail, for example, P50) or high-tension aluminum alloy shapes. These shapes under agreement with the manufacturers might be supplied with appropriate certificates to any region of Russian Federation, where a certain version of STU will be implemented.

As a rail compound it is supposed to make use of certified high-tension galvanized steel wire of 3mm diameter (ЖБК ТС71915393-053-06) in accordance with GOST 7348-81.

This type of wire is produced by Volgograd factory "VolgoMetiz", which is the part of Cherepovets holding company. Sample lot of this wire was produced on STU Ltd request in 2007. 4mm, 5mm, 6mm and other diameter wire might also be in use. According to SNiP 2.05.03.84* "Bridges and pipes", reinforced ropes which consist of 3-5mm diameter wires might be in use in regions with an average temperature of -40°C. In fact, the string represents multi-wire unrolled rope, which is assembled on a building area with the help of separate wires. The string is located in a close rail channel protected with encapsulating material, which is an anticorrosive agent. That is why in accordance with the requirements, min. 3mm diameter wire without zinc or any other protective covering can be used.

STU track structure and supports are built structures, which are installed directly on a building area. That is why "the second level" transport line doesn't have to be certified, such as other analogous built structures like roads, railways, bridges, viaducts, causeways, etc.

Taking into account the availability of facilities, technologies and equipment in Russia and in foreign countries, STU track structure and supports might be developed and installed in any region of Russian Federation including the Northlands.

5.3 Infrastructure

STU infrastructure consists of stations, depots, etc. Their functions are similar to the functions of bus stations and depots, which installation process is already worked out.

Constructional and finishing agents, elevators, lifting devices, sanitary ware and other equipment which is in use of STU infrastructure might be purchased from the best certified manufacturers. It will provide high quality and reliability of this equipment.

Price and other specifications of constructional materials and station equipment might be corrected by the customer in the developmental stage. These changes shouldn't provoke deterioration in quality and reliability of the construction project.

Construction and handover of such projects is implemented in accordance with GOSTs, SNIPs and other normative documentation worked out by the Russian Federal Agency for Construction, Housing maintenance and Utilities.

Thus, taking into account the availability of facilities, technologies and equipment in Russia and in foreign countries, STU infrastructure might be developed and installed in any region of Russian Federation including the Northlands.

5.4 Development and Expert Evaluation of Design and Estimate Documentation

STU design and estimate documentation, STU track and infrastructure building and their introduction into service are the similar as the designing and building of bridges, high-rise structures and other complicated construction projects.

6. STU Implementation Specifics

Documentation submitted to estimate and all abovementioned facts prove that the project designer has serious intentions to implement STU project to transport sector of Russian Federation. A large scope of research and development work has been implemented. But still there is a question of interest:

How will STU behave in terms of permanent frost, and will it retain its normal operation and technical and economic features in the longer term?

The climate in the North of Russia is characterized with large temperature gradient (about 100°C), high winds, high humidity and permafrost. The abovementioned temperature gradient and wind are taken into account in the estimates. But permafrost influence on a string-rail track evenness, which is a weak spot of any high-speed transport system including STU, is not adequately researched. And it is permafrost that can disturb required ideal evenness of a track. This fact can negatively influence STU implementation in the Northland, if it is taken into account in a wrong way.

6.1. About Permafrost Influence on STU

It is known that in terms of permafrost, which specifies so-called cryolithic zone of the Northern regions of Russia, such processes as thermokarst, frost fracturing and frost lift of dispersive ground may occur.

Thermokarst is the formation of subsidence and downwarping land forms due to melting of ground ice or melting of frozen ground. Thermokarst is caused by exchange flux on the land surface, when the depth of season melting exceeds the depth of ground ice lay or icy frozen ground.

Frost fracturing of ground surface is caused by freezing due to in-depth nonuniform temperature distribution in frozen earth materials. In such case compression and tension stress take place and lead to earth materials crevice and crack formation.

Frost lift of dispersive grounds comes from ground surface lift, caused by increase of frozen moisture, and ice formation, due to water migration at soil freezing.

The abovementioned permafrost peculiarities have negative influence on building of conventional roads. The roads lay on the ground, which stores heat in summer. It results in uneven frost melting and ground subsidence.

According to the estimates of the project designer, STU doesn't have such disadvantages due to its partial reference to permafrost. STU foundation piles are installed at sufficient depth and are made in such a way that they don't store heat and they transfer freeze into the depth of permafrost in winter, which provides stabilization of the foundation piles for the whole period of "the second level" track exploitation. Such solutions are already in use (for example, gas pipe-line in Alaska, open pile foundations of high-rise buildings in the Northland, etc.). But concerning STU additional researches should be conducted. Though SNiP 2.05.03.84* "Bridges and pipes" stipulates designing of bridges in terms of permafrost, and the project designer has the license № ГС-1-99-02-26-0-77045332-62-038379-1 dated on 02/05/2006 issued by the Russian Federal Agency for Construction, Housing Maintenance and Utilities. According to the license STU may design buildings and constructions (including high-speed lines) in the regions with severe geotechnical conditions (subsident, bulging, karst and deeply frozen). Still STU implementation in such regions has specific requirements.

Suspended STU is more resistant to the influence unstable actions of ground freeze. But it is influenced by strong crosswinds due to small bending and torsional stiffness of a string rail. It should be mentioned that the project designer has studied maximum deflection angle of Ю-372П unibus cabin in terms of the overall impact of maximum asymmetric location of the passengers and the force of stormy crosswind (3.5° slope angle). Still these researches should be continued taking into consideration supports installment on permafrost grounds. Effective operational experience of ropeways, where ropes don't have torsional stiffness at all, proves that the problem has technical solutions, but additional researches have to be conducted.

6.2 About STU High Technological Effectiveness

The abovementioned concept in our case includes string-rail manufacturing technology, supports installment technology, and the way pre-tensioned string rails are mounted on supports.

String-rail manufacturing technology is rather simple. There is rail top and rail body industrial rolling, placement and fixing of reinforcing ropes in it, filling of a rail body, welding of a long, narrow metallic strip to a rail body for unibus wheeling. These procedures require approx. 50-75 kg per 1 running meter (the same amount is needed for manufacturing of a conventional rail). All these procedures are less complicated than building of huge steel-reinforced concrete bridges with large spans or installation of monorail beam trestles. The designer has already demonstrated effective filling of a long and narrow string body with concrete, made without cracks and splits. Testing took place in experimental area in Ozyory-town. The concrete was squeezed to the pipe with the inner diameter of 82mm filled with nine K-7 ropes with the inner diameter of 15.2 mm at a temperature of -7°C.

A string serves as a principal reinforcement in a string-rail. That is why requirements to it will be the same as the requirements to pre-tensioned reinforcement of concrete structures. As the concrete is squeezed to a close rail frame, it follows that ready-mounted string-rail represents a concrete pipe. And it is easier to control and eliminate the process of cracks and splits occurrence, which weakens the construction, than it is in conventional reinforced concrete structures. As the external surface of concrete is all around covered with solid steel sheet, it will help to eliminate moisture penetration to the concrete. Thereafter, it will help to eliminate corrosion of the steel ropes and will increase their service life in comparison with conventional reinforced concrete bridges, which service life is approx. 50-100 years.

Supports installment technology and string-rail mounting to the supports in summer might be implemented with the help of special manufacturing equipment. At the same time there is no need of building access roads or platforms, because the string rails might be mounted on the supports from already installed sites of a track structure. In winter, when the ground is frozen, the installment might be implemented in accordance with a simpler process scheme.

6.3 About Transportation Process Safety in STU and its Convenience

STU transport system, as any other high-speed system, is rather sensitive to external actions, including mechanical influences. But it should be mentioned, that in distinction from conventional rail transport STU is equipped with anti-derailment system. It will considerably decrease the possibility of unibus derailment. And it should be also mentioned, that it would be more difficult for terrorists to put any hazardous large items at a height of 5-6 and more meters on narrow rails, than it might be done to unactivate conventional railroads.

Due to the possibility of permafrost influence on STU, track structure may become uneven. That is why the supports should be equipped with track adjusting mechanisms, which eliminate the effects of supports leans and sagging.

While moving across certain string-rail sites (in the top and in the final quarters of each span the bottom of a mono-unibus might be inclined. This incline is supposed to be in the limits of admissible inclination value of bottoms of city automobile, tram and bus transport.

In case of emergency passengers' psychological state won't be critical. If the unibus gets out of order away from the station at snow-storm, the passengers are supposed to be immediately transported to the station by the moving next properly functioning unibus. Unibus traffic interval is supposed to be 1-2 min.

6.4 About Technical State Diagnostics of a Track and its Maintainability

The diagnostics of technical state of a string-rail track may be implemented with the help of sensors installation. The sensors should control unibus state and transfer data to the diagnostics service division.

The rate of track maintainability is rather high. For example, a closed pre-tensioned STU string is less unstable than an open pre-tensioned rope of a conventional ropeway. But in case of string break off, caused by any reasons, its pre-tension force (up to 500t) will cause decrease of length in a special rail channel. The string will get out of order, but at the same time pre-tension force in a string rail will decrease (rail top and rail body pretension will remain, i.e. 20-30 per cent of primary tension). Basic equipment may proceed on such a track, and the string may be replaced or strengthened with additional external strings in the shortest possible period of time. If such emergency situations occur during exploitation of conventional bridges (for example, stay cable or load cable break off, or abruption of pre-tensioned reinforcement strand) it will lead to bridge collapse and long-lasting repair.

7. Conclusions and Recommendations

7.1. The designer presented plenty of documentation, which provides the idea of STU objectives, goals, investment character, principles and directions of STU implementation in Russian Federation and abroad.

In terms of transport system development of any region of Russian Federation, and in general, STU might be implemented as one of its constituent parts along with the implementation of conventional transport systems.

7.2. To put STU implementation into practice, it is necessary to move from investment stage of a project to engineering design, which will take into account construction and service peculiarities of "the second level" transport system in certain climatic conditions. Precise estimate of any STU project might be fulfilled only after design work on a particular STU version has been implemented. In this case all necessary analyses and explanations will be carried out. And adequate engineering solutions concerning infrastructure, track structure and rolling stock will be introduced.

7.3. On the stage of engineering design additional range of works, aimed at providing STU with effective implementation, should be completed. When high-speed passenger STU will be in the stage of implementation, additional researches concerning STU safety and reliability (towards passengers and personnel life, health and property) should be conducted. Comfort psychological state of passengers should also be taken into consideration.

7.4. Taking into account the development of the Transport Strategy of Russian Federation till 2030 and the tendencies in transportation industries of the country, STU designer should initiate in accordance with the established procedures a special-purpose program of state and private cooperation. It will be concerned with the implementation of projects of federal significance and with the creation of a new transport system in Russian Federation, which is String Transport.

To make a real step in such cooperation, it is reasonable to construct all basic types of track structures and STU versions on the experimental area of the Technology Development zone in the town of Dubna (Russian Special Economic zone, which resident is STU-Dubna Ltd, subdivision of STU Ltd) in order to carry out prototype testing and further certification.

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