**MINISTRY FOR INVESTMENT AND DEVELOPMENT
OF THE REPUBLIC OF KAZAKHSTAN**

Roads Committee

Kazakhstan Highway Research Institute

CHARACTERISTICS OF HIGHWAY SUBGRADE FROST PENETRATION IN REGIONS OF THE KAZAKHSTAN

Prof. Bagdat Teltayev

Askhat Baibatyrov

Elena Suppes

THE REPUBLIC OF KAZAKHSTAN

Map of highways of the Republic of Kazakhstan

Russia

China

Uzbekistan

Turkmenistan

Kyrgyzstan

Total area - 2 724 900 sq.km

(9th in the world)

The total length of highways - 130 000 km

Public highways   - 96 700 km
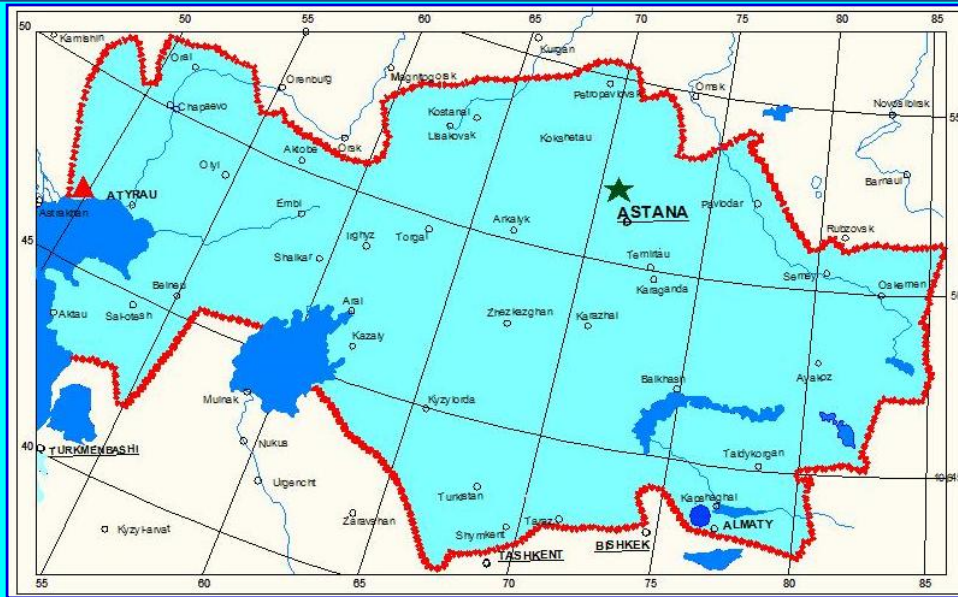
**Highways with hot mix
asphalt pavement   - 21 200 km**

Population   - 17,0 mln. people

Climate   - sharply continental

Temperature: in the south in summer +50 ºC
in the north in winter   -52 ºC
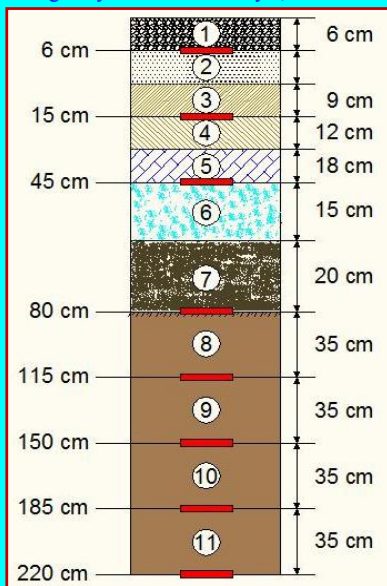
2

LOCATIONS OF EXPERIMENTAL SECTIONS

Highway	Simbol	Air temperature, ºC		Freezing duration, day	Frost penetration depth, cm
		maximum	minimum		
Astana-Burabay	★	+36,0	-42,0	176	245
Almaty-Bishkek	●	+38,0	-28,0	93	147
Atyrau-Aktobe	▲	+48,0	-39,0	63	147

3

PAVEMENT STRUCTURES AND LOCATIONS OF SENSORS

Highway "Astana-Burabay" , km 76+30

6 cm — 6 cm ①
— ②
15 cm — 9 cm ③
— 12 cm ④
45 cm — 18 cm ⑤
— 15 cm ⑥
— 20 cm ⑦
80 cm —
115 cm — 35 cm ⑧
150 cm — 35 cm ⑨
185 cm — 35 cm ⑩
220 cm — 35 cm ⑪
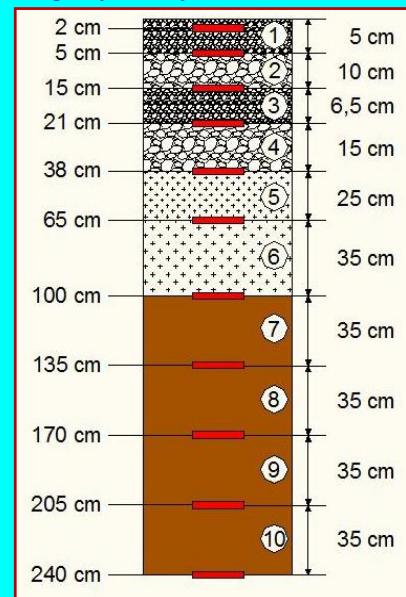
1-stone mastic asphalt
2-geogrid
3-coarse-grained asphalt
4-black crushed stone
5-crushed stone and sand mix + cement of 7%
6-crushed stone and sand mix
7-sand
8-11-ubgrade soil – heavy sandy clay loam
▬ -sensors

Highway "Atyrau-Aktobe" , km 598+50

2 cm — 8 cm ①
10 cm — 6 cm ②
20 cm — 11 cm ③
30 cm — 5 cm ④
— 60 cm ⑤
90 cm —
115 cm — 25 cm ⑥
140 cm — 25 cm ⑦
165 cm — 25 cm ⑧
190 cm — 25 cm ⑨
215 cm — 25 cm ⑩
240 cm — 25 cm ⑪
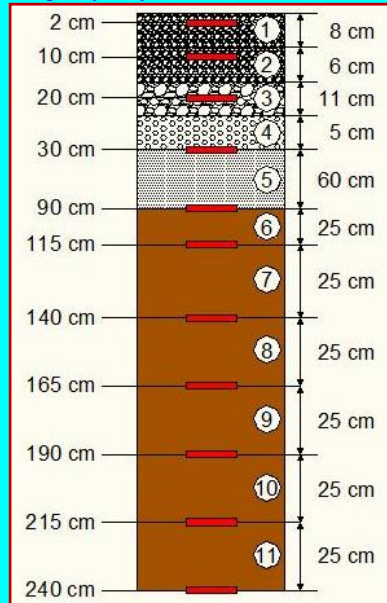
1-stone mastic asphalt
2-coarse-grained asphalt
3-coarse-grained high-porous asphalt
4-black crushed stone
5-sand and gravel mix
6-11-subgrade soil – dusty sand
▬ -sensors

Highway "Almaty-Bishkek", km 58+895

2 cm — 5 cm ①
5 cm — 10 cm ②
15 cm — 6,5 cm ③
21 cm — 15 cm ④
38 cm — 25 cm ⑤
65 cm — 35 cm ⑥
100 cm — 35 cm ⑦
135 cm — 35 cm ⑧
170 cm — 35 cm ⑨
205 cm — 35 cm ⑩
240 cm —

1-fine-grained asphalt
2-coarse-grained asphalt
3-old fine-grained asphalt
4-old cold asphalt
5-6-sand and gravel mix
7-10-subgrade soil – heavy sandy clay loam
▬ -sensors

4

PLACING OF TEMPERATURE AND MOISTURE SENSORS

View of experimental section

Upper part of measuring equipment

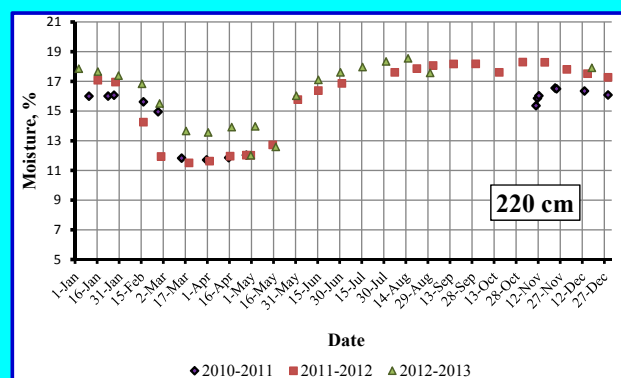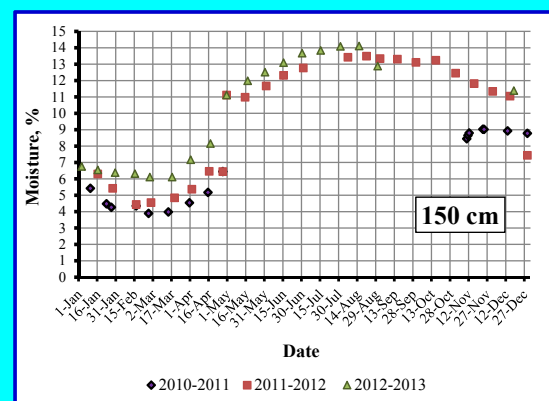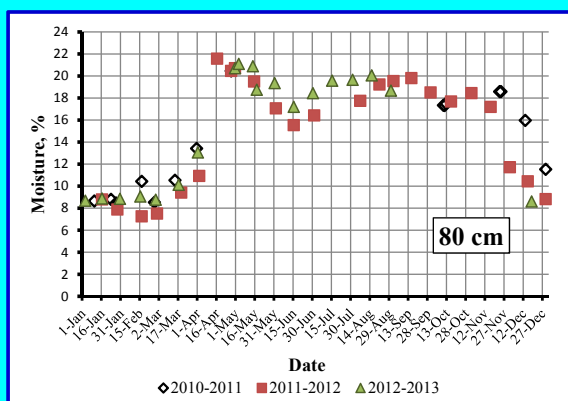General view of a complex of sensors

Installation of a sensor

5

SEASONAL VARIATION OF MOISTURE IN SUBGRADE
OF THE HIGHWAY "ASTANA-BURABAY"

80 cm

150 cm

220 cm

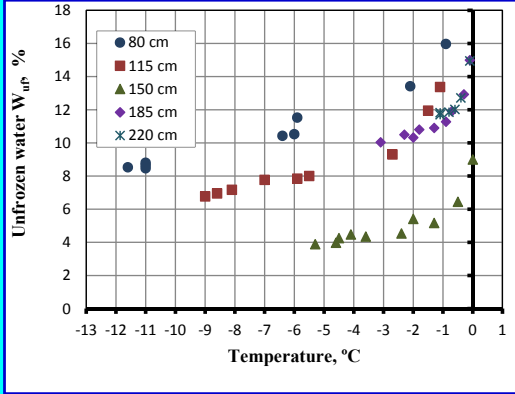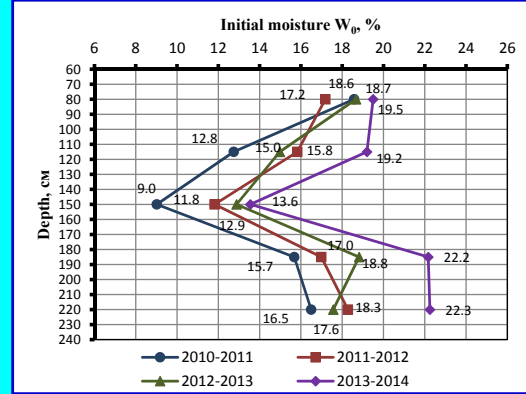◆2010-2011 ■2011-2012 ▲2012-2013
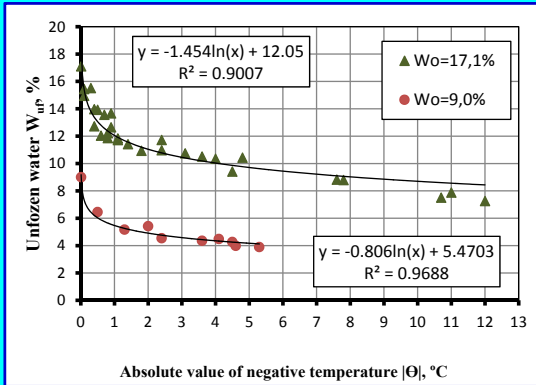
6

UNFROZEN WATER AND INITIAL MOISTURE

Dependence of unfrozen water content on negative temperature

Distribution of initial moisture in subgrade of highway "Astana-Burabay" on depth

Dependence of unfrozen water content on temperature


$$W_{uf} = a + b \cdot \ln|\theta|$$

W_{uf} - unfrozen water content, %;
$|\theta|$ - absolute value of negative temperature, ºC;
a, b - regression coefficients.

7

CORRELATION EQUATION FOR UNFROZEN WATER

Values of correlation coefficients *a* and *b*

Initial moisture W_0, %	Coefficients		R^2
	a	b	
9,0	5,470	-0,80	0,968
11,8	6,865	-1,10	0,955
13,1	9,039	-1,13	0,514
15,5	11,660	-1,06	0,789
17,1	12,050	-1,45	0,900
18,9	12,870	-1,61	0,833
22,3	15,380	-1,55	0,986

Dependence of coefficient *a* on initial moisture
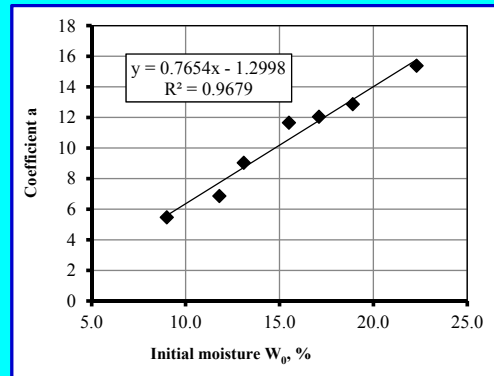
$$a = -1,299 + 0,765 \cdot W_0,$$

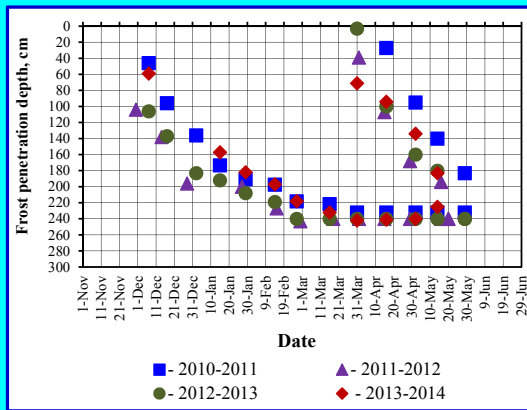$$b = -0,316 - 0,60 \cdot W_0,$$

W_0 – initial moisture, %

$$W_{uf} = -1,299 + 0,765 \cdot W_0 - 0,316 \cdot \ln|\theta| - 0,60 \cdot W_0 \cdot \ln|\theta|$$

Dependence of coefficient *b* on initial moisture

8

FROST PENETRATION AND THAWING IN HIGHWAYS

Highway "Astana-Burabay" (2010-2014)

Highways "Almaty-Bishkek" and "Atyrau-Aktobe" (2013-2014)
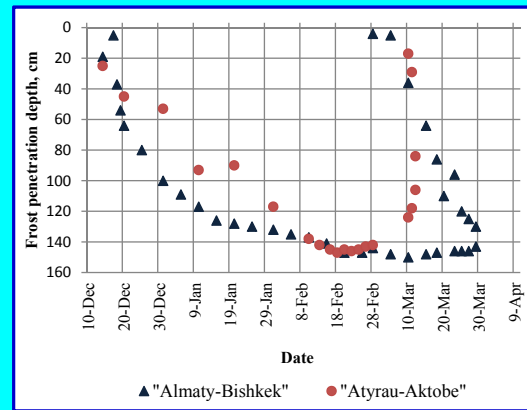
Highway	Freezing duration, day	Frost penetration depth, cm
Astana-Burabay	176	245
Almaty-Bishkek	93	147
Atyrau-Aktobe	63	147

CONCLUSIONS

1. In whole territory of Kazakhstan in winter highway subgrade freezes.

2. It was experimentally established that on the southern and western regions depth of frost penetration reaches 147 cm, and in the north reaches 245 cm.

3. Frost penetration duration on the southern, western and northern regions amounted to 93, 63 and 176 days, respectively.

4. According to the results of experimental studies a reliable correlation dependence of unfrozen water amount in the highway subgrade on initial moisture and absolute value of negative temperature have been established.

Thank you for your attention!