Estimation of freeze thaw cycles based on the meteorological data of Mongolia

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Cold weather concrete International norms Mongolia
Freeze thaw cycles Metrological data

1. Introduction

Mongolia is a cold and dry country with high elevation. Its extreme continental climate results in short summers and long, cold winters. Therefore, Mongolia's climatic fluctuations are very high in spring and autumn. During the daytime, the temperature rises above 10 degrees Celsius, but at night it often drops to subzero level. These temperature fluctuations create several freeze-thaw cycles[1)], which adversely affect the durability of concrete structures. Therefore, this study aims to estimate the freezing and thawing cycles, which can be occurred within a year, based on the metrological data of Mongolia. Moreover, the applicable period for cold weather concreting in Mongolia is estimated according to international norms and guidelines.

2. Estimations Based on Meteorological data of Mongolia.

2.1 Meteorological data of Mongolia

In this study, metrological data of all Mongolian provinces were collected for the last decade (2010-2020). The meteorological data are given in Table 1 and location of the cities are shown in Fig.1.

2.2 Estimation of freeze and thaw cycles

It is well known that the freeze-thaw cycles within a year, in which concrete structures have received, can be estimated from the meteorological factors[2)]. The following equations (1)–(3) were used to calculate the Cy_{ASTM}-sp.

$$C_{\mathrm{yASTM-sp}} = C \cdot F \cdot s \cdot p \cdot R_{a90} \quad (1)$$

$$T = -T_{amin}\left(1 - D_f / D_w\right) \quad (2)$$

$$R_{a90} = 4.2T - 5.4 \quad (3)$$

Table 1. ASTM equivalent number of cycles based on the meteorological data of Mongolia, 2010-2020

Location			Metrological data					
Countries	Code	Regions	Annual extreme value of daily minimum temperature ($T_{a\,min}$, °C)	Duration of freezing days (D_f, days)	Total number of days for freeze and thaw (D_w, days)	Regional factor T	Ra_{90} (cycle/year)	CyASTM-sp (cycle/year)
Japan	**SAP**	Sapporo	-14.9	46	81.9	6.5	22	3.0
	SEN	Sendai	-7.4	1	62	7.3	25	3.5
Mongolia	**UB**	Ulaanbaatar	-36.6	130	202	13.0	49	6.8
	DA	Darkhan-uul	-39.0	125	191	13.5	51	7.1
	OR	Orkhon	-41.1	125	194	14.6	56	7.8
	KHU	Khuvsgul	-34.1	128	203	12.6	48	6.6
	ZA	Zavkhan	-39.8	124	205	15.7	61	8.4
	BU	Bayan-Ulgii	-43.9	131	220	17.8	69	9.6
	GA	Gobi-Altai	-37.1	119	195	14.5	55	7.7
	UM	Umnugobi	-38.4	132	214	14.7	56	7.8
	DG	Dornogobi	-30.5	97	169	13.0	49	6.8
	DO	Dornod	-34.3	104	174	13.8	53	7.3
	KHE	Khentii	-36.7	125	195	13.2	50	6.9

Fig.1 Location of the Mongolian cities

Table 2. Applicable period for cold weather concrete work in Mongolia, 2010-2020

Location			Mongolian norm (BNbD52-02-05)		ACI 306R-16		AIJ Recommendation		Applicable period	
			Period when daily average temperature below 5 ˚C		Period when daily average temperature 4 ˚C or less		Period when accumulated temperature (M_{91}) is below than 840 °D·D			
Countries	Code	Regions	start	end	start	end	start	end	start	end
Japan	SAP	Sapporo	-	-	21-Nov	31-Mar	11-Nov	31-Jan	**11-Nov**	**31-Mar**
	SEN	Sendai	-	-	11-Dec	10-Mar	-	-	**11-Dec**	**10-Mar**
Mongolia	UB	Ulaanbaatar	28-Sep	24-Apr	8-Oct	20-Apr	8-Sep	16-Feb	**8-Sep**	**24-Apr**
	DA	Darkhan-uul	7-Oct	10-Apr	9-Oct	6-Apr	13-Sep	18-Feb	**13-Sep**	**10-Apr**
	OR	Orkhon	27-Sep	22-Apr	27-Sep	20-Apr	7-Sep	17-Feb	**7-Sep**	**22-Apr**
	KHU	Khuvsgul	6-Oct	20-Apr	7-Oct	9-Apr	6-Sep	12-Feb	**6-Sep**	**20-Apr**
	ZA	Zavkhan	26-Sep	24-Apr	6-Oct	20-Apr	8-Sep	20-Feb	**8-Sep**	**24-Apr**
	BU	Bayan-Ulgii	6-Oct	19-Apr	6-Oct	10-Apr	7-Sep	13-Feb	**7-Sep**	**19-Apr**
	GA	Gobi-Altai	25-Sep	11-May	27-Sep	8-May	1-Sep	24-Feb	**1-Sep**	**11-May**
	UM	Umnugobi	22-Oct	6-Apr	24-Oct	28-Mar	23-Sep	30-Jan	**23-Sep**	**6-Apr**
	DG	Dornogobi	22-Oct	6-Apr	23-Oct	28-Mar	22-Sep	2-Feb	**22-Sep**	**6-Apr**
	DO	Dornod	9-Oct	17-Apr	9-Oct	17-Apr	12-Sep	11-Feb	**12-Sep**	**17-Apr**
	KHE	Khentii	28-Sep	20-Apr	9-Oct	12-Apr	9-Sep	13-Feb	**9-Sep**	**20-Apr**

Where, $C_{\mathrm{yASTM-sp}}$ is ASTM equivalent number of cycles, considering coefficients (cycles per year); R_{a90} is ASTM equivalent number of cycles when relative dynamic modulus of elasticity is 90% (cycles/year); T is regional factor; T_{amin} is annual extremes of daily minimum temperature (°C); D_f is duration of freezing period (days); D_w is total number of freeze-thaw days (days); C, F, s, p is coefficients for curing conditions, freeze-thaw conditions, solar radiation conditions, deterioration process coefficient, respectively.

2.3 Estimations for applicable period for cold weather concreting

Mongolia has no separate cold weather guidelines. Instructions for cold weather concreting are included in chapter 9 of BNbD52-02-05. Therefore, to estimate the applicable period for cold weather concreting, a comparison was made with two international norms. The first one is the American Concrete Institute (ACI) Report ACI 306 R-16. Second is the Architectural Institute of Japan (AIJ) guidelines for recommendation for practice of cold weather concreting.

3. Results

3.1 Estimation of freeze and thaw cycles

Table 1 shows the calculation results of the ASTM equivalent number of freeze-thaw cycles based on meteorological data of Mongolia. According to the result, ASTM equivalent number of cycles R_{a90} was 48 to 69 cycle/year at all locations and ASTM equivalent number of cycles $C_{\mathrm{yASTM-sp}}$ was 7 to 10 cycle/year at all locations as shown in Fig.2. Therefore, $C_{\mathrm{yASTM-sp}}$ is more realistic than R_{a90} for the natural cold weather conditions.

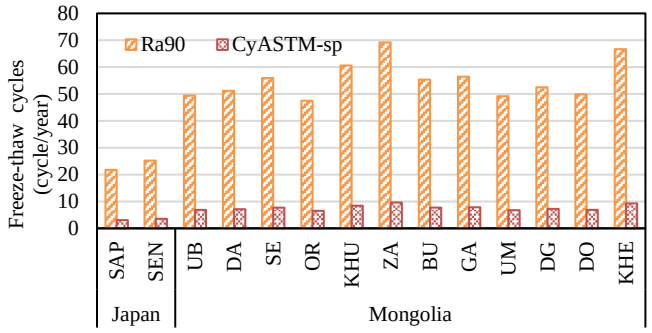

Fig.2 Freeze-thaw cycles within a year

3.2 Estimations for applicable period for cold weather concreting

Table 2 shows the calculation results of the applicable period for cold weather concrete work in Mongolia. There is no significant difference between 4 ˚C and 5 ˚C when applied as the daily average temperature. However, AIJ recommendation that the accumulated temperature (M_{91}) is more severe condition to satisfy in Mongolia because starting date is always earlier about 30 days in most of the locations. The starting date of cold weather concreting was at the beginning of September and the finishing date was mid-April. The duration of cold weather concreting was between 195 and 252 days, depending on the location.

4. Conclusions

The following conclusions can be drawn from this study.

1) According to result, ASTM equivalent number of cycles R_{a90} was between 48 and 69 cycle/year, depending on the locations.
2) ASTM equivalent number of cycles $C_{\mathrm{yASTM-sp}}$ was between 7 and 10 cycle/year at all locations in Mongolia.
3) The applicable period of cold weather concreting was between 195 and 252 days, depending on locations in Mongolia.

References

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