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MECHANICAL PROPERTIES OF SELF CURING CONCRETE INCORPORATING PEG400

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Abstract:
According to lack of water, labor self curing concrete (SCC) is Necessary in construction projects. In this study it was focus on concrete application with new admixture to achieve SCC. The present study involves the use of shrinkage reducing admixture polyethylene glycol (PEG 400) in concrete which helps in self curing and better hydration and hence strength gain. The affect of admixture (PEG 400) on water retention, compressive strength, split tensile strength and modulus of rupture by varying the percentage of PEG by weight of cement from 0% to 1% were studied for M1 and M2 mixes. It was found that PEG 400 could help in achieving self curing by giving strength on par with conventional curing. It was also found that 0.5% of PEG 400 by weight of cement was the optimum for both M1 and M2 mixes.

الملخص :
نظرا لنقص المياه ، فإن الخرسانة ذاتية المعالجة (SCC) ضرورية في مشاريع البناء .في هذه الدراسة كان التركيز على تطبيق الخرسانة مع خلط ماده جديدة لتحقيق SCC. تشتمل الدراسة الحالية على استخدام خليط تخفيض من انكماش البولي إيثيلين جيليكول (PEG 400) في الخرسانة مما يساعد في المعالجة الذاتية ويساعد في ترطيب أفضل وبالتالي على مقاومة الخرسانة .تمت دراسة تأثير إضافة (PEG 400) على احتباس الماء وقوة الانضغاط وقوة الشد المنفصلة ومعامل التمزق من خلال تغيير نسبة PEG من وزن الأسمنت من 0٪ إلى 1٪ للخلطات M1 و M2 .وجد أن PEG 400 يمكن أن يساعد في تحقيق المعالجة الذاتية من خلال إعطاء القوة على قدم المساواة مع المعالجة التقليدية .كما وجد أن 0.5٪ من PEG 400 من الوزن الأسمنتي هو الأمثل لكل من M1 و M2 .

Keywords: Self-curing concrete; Water retention; Relative humidity; Hydration; Absorption; Permeable pores; Sorptivity; Water permeability.

1. Introduction:

Curing is the maintaining of a satisfactory moisture content and temperature in concrete during its early ages so that desired properties (of concrete) may develop. Curing is essential in the production of concrete that will have the desired properties. The strength and durability of concrete will be fully developed only if it is cured. No action to this end is required, however, when ambient conditions of moisture, humidity, and temperature are sufficiently favorable to curing. Otherwise, specified curing measures shall be discussed [1].

New developments in curing of concrete are on the horizon as well. In the next century, mechanization of the placement, maintenance, and removal of curing mats and covers will advance as performance-based specifications quantify curing for acceptance and payment. In addition, effective sealants and compounds that prevent the loss of water and promote moist curing conditions will be in high demand. Self-curing concrete should become available in the future [2].

1.1. Advantages of Self Curing Concrete [3, 7, 8, 9, 16, 17]

- Reduces autogenously cracking.
- Self-curing.
- Reduce the permeability.
- Increases mortar strength and early age strength sufficient to withstand strain.
- Greater utilization of cement.
- Lower Maintenances.

2.1. Literature Review and Research Objective

Junaid et. al. [10] (2015) made a comparison between the conventional cured concrete and self-curing concrete by adding admixture polyethylene glycol (PEG-4000, 1% weight of cement) in concrete which helps in self-curing and in better hydration and hence strength. The results show that the Concrete cured internally using 1% PEG-4000 attained more compressive strength than conventional cured concrete.

Indirajith et. al. [11] (2016) carried out comparative experimental tests between self-curing concrete (both external self-curing and internal self-curing) by using PEG and conventional concrete for M20, M25 and M40 grade. Self-curing concrete resulted in better hydration with time under drying condition compared to conventional concrete. Slump value increases with increase in the quantity of PEG. It was studied that the strength increases at different proportions of PEG i.e, 1% is optimum for M20 and M25 grade 0.5% for M40 grade and 0.3% for high strength self curing concrete.

El-Dieb et. al [12] (2012) studied the effect of using polyacrylamide (PAM) and polyethylene glycol (PEG) with a dosage of 0.02% by weight of cement as self-curing agents on the degree of hydration, water retention, permeable pores, water absorption, and microstructural characteristics of Portland cement mixes with 8% silica fume and without silica fume as cement replacement. Using PAM and PEG as self-curing agents were more effective in improving the water retention and the degree of hydration in mixes containing 8% silica fume cement replacement. The use of PAM and PEG resulted in samples with a denser microstructure, fewer and smaller crystalline hydration products, and thinner micro cracks.

Bashandy [13] (2015) investigated the performance of ordinary concrete (OC) and self curing concrete (SCC) at elevated temperature from 200c^o to 600c^o ,after subjected to elevated temperature, the samples are cooled down in water or air and stored for 1 and 28 days and then mechanically tested. The test results show that the reduction of strength of self curing concrete increases with the exposed period and the elevated temperature. Compressive strength and tensile strength test results of SCC always drop with elevated temperature. Air cooling is more effective compared to water cooling at high temperature.

Kumar et. al [14] (2015) studied the effect of polyethylene glycol 200 on strength characteristics of Self-curing concrete by varying percentage from 0% to 2% by weight of cement for both M20 and M40 grades of concrete. The compressive strength increased for both PEG and PEA at 1% compared to conventional concrete for M25.

Vedhasakthi et. al [15] (2014) investigated the strength characteristics and workability of normal and high strength concrete using polyethylene glycol (PEG) and sorbitol as self curing agents. The results show that using peg more effective than using sorbitol. There is increase in the strength of (HSSCC) high strength self curing concrete than conventionally cured high strength concrete.

Based on the above-mentioned literature review, an effort is made in the present investigation to compare the conventional cured concrete with internally cured concrete by adding water retaining admixture "polyethylene glycol" (PEG-400 0.3%, 0.5% and 1% weight of cement) which helps in self-curing and in better hydration.

2. EXPERIMENTAL PRPGRAM

2.1. Materials Properties and Design Mix Cement:

A locally produced ordinary Portland cement complied with E.S.S.373/91 requirements was used [4].

Aggregate:

The fine aggregate was siliceous natural sand. The coarse aggregate was crushed dolomite of maximum nominal size 14 mm was used.

Fly ash:
The mineral admixture used in this experimental program is fly ash under a commercial name of Supper Pozz-5. [5]

Viscosity Enhancing Agent (VEA):
The super-plasticizer used in this experimental program under a commercial name of Sika-Viscocrete 3425 from Sika Egypt [6].

Water:
Ordinary potable water without acidity and alkanity available in the laboratory was used.

Polyethylene glycol-400:
PEG-400 are added at rate of 0.3%, 0.5% & 1% of cement weight.

Table (1) Material required per cubic meter of concrete

Speci-mens	MIX	cem-ent	gravel	sand	Fly ash	Superp-lastizer	water	PEG %	Curing
M11	M1	366	1128	817	19	7.7	140	-	WC
M12		366	1128	817	19	7.7	140	-	SC
M13		366	1128	817	19	7.7	140	0.3	SC
M14		366	1128	817	19	7.7	140	0.5	SC
M15		366	1128	817	19	7.7	140	1	SC
M21	M2	440	1220	520	-	-	154	-	WC
M22		440	1220	520	-	-	154	-	SC
M23		440	1220	520	-	-	154	0.3	SC
M24		440	1220	520	-	-	154	0.5	SC
M25		440	1220	520	-	-	154	1	SC

Where WC: Water Curing, SC: Self Curing

3. EXPERIMENTAL SETUP

The experimental program investigated the strength of self curing concrete by adding poly ethylene glycol PEG400 0.3%, 0.5% and 1% by weight of cement. The experimental program was aimed to study the water retention, compressive strength, split tensile strength and modulus of rupture. To study the above properties mixes M1 and M2 were considered. The scheme of experimental program is given in Table (2).

Table (2) Experimental program

Desig-nation	Nature	M1			M2		
		Cube	Cylinder	prism	Cube	Cylinder	prism
1	Plain (water Curing)	9	9	3	9	9	3
2	Plain (Air Curing)	9	9	3	9	9	3
3	PEG 0.3%	9	9	3	9	9	3
4	PEG 0.5%	9	9	3	9	9	3
5	PEG 1%	9	9	3	9	9	3

The cube size is 100 × 100 ×100 mm. The cylinder size is 100 mm in diameter and 200 mm in height. The prism size is 100 × 100 × 500 mm.

2.2. Testing:

2.2.1. Water Retention Test

Water Retention is the ability of the substance to retain water calculates according the following equation. Weight loss with age was measured to evaluate the water retention of the mix. In both mixes, the weight loss for mix without self-curing agent is more than mix including self-curing agent. This shows better water retention for self-curing mixes. The weight of cubes at different ages for M1 and M2 are shown in the Table 3 &4.

$$\text{Weight losses ratio\%} = (W_0 - W_1)/ W_0 \quad (1)$$

Table (3) Average weight loss of cubes for Mix M1

Desig-nation	Curing Period (days)							Weight losses ratio
	0	3	7	10	14	20	28	
M11	0	-	0.015	-	0.024	-	0.15	-
M12	0	0.037	0.042	0.056	0.061	0.062	0.0633	1
M13	0	0.022	0.024	0.042	0.05	0.048	0.0327	0.516
M14	0	0.0245	0.0282	0.049	0.054	0.05	0.037	0.584
M15	0	0.0294	0.0314	0.052	0.057	0.056	0.0408	0.644

Table (4) Average weight loss of cubes for Mix M2

Desig-nation	Curing Period (days)							Weight losses ratio
	0	3	7	10	14	20	28	
M21	0	-	0.0246	-	0.028	-	0.041	-
M22	0	0.046	0.052	0.059	0.067	0.079	0.093	1
M23	0	0.023	0.026	0.029	0.034	0.041	0.051	0.5484
M24	0	0.0305	0.0334	0.036	0.042	0.049	0.06	0.6452
M25	0	0.036	0.0404	0.044	0.051	0.0607	0.068	0.73

2.2.2. Compressive Strength

The specimens are subjected to air-curing and water-curing. The cube specimens of size 100mm X 100 mm X 100 mm were tested on compression testing machine.

$$f_c = 0.95\, p/A, \ \text{MPa} \qquad (2)$$

Where, p= is the maximum load in Newton applied to the specimen

A= is the cross-sectional area (mm2)

2.2.3. Split Tensile Strength Test

The cylinder specimens of size 150 mm diameter and 300 mm height were tested on universal testing machine and the load is applied until the failure of cylinder along the vertical diameter

$$f_{ct} = 2\,P / \pi\, d\, l \quad \text{MPa} \qquad (3)$$

where P = maximum load in Newton applied to the specimen

l = length of the specimen (in mm),

d = cross sectional dimension of the specimen (in mm)

2.2.4. Flexural Strength Test

It is the ability of beam to resist failure in bending. The beam specimens of size 100 mm X 100 mm X 500mm were tested on compression testing machine. The flexural strength is expressed as modulus of rupture in N/mm².

$$f_b = p\, l / b\, d^2 \quad \text{MPa} \qquad (4)$$

Where *p* = maximum load in Newton applied to the specimen

l = length of the specimen (in mm),

b = breadth (in mm),

d = depth (in mm).

3. Results and Discussion

3.1. Water Retention:

From Figures (1), (2) it is clear that the Mix M1 self-curing self compact concrete with 0.3% dosage of lower molecular weight polyethylene glycol (PEG 400) shows least weight loss compare to other dosages (0.5% and 1%). Similarly from Mix 2 self-curing conventional concrete with 0.3% dosage of PEG 400 shows better water retention compare to other dosages. But when mix with lower w/c ratio together with super-plasticizer shows better water retention (lower value in weight loss) compare to mix with higher w/c ratio and without super-plasticizer.

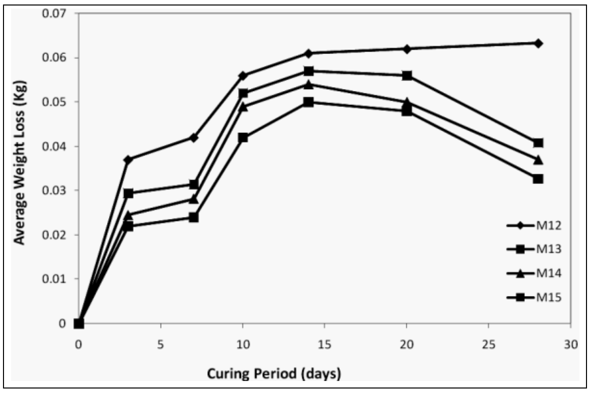

Figure (1) The Effect of Polyethylene-Glycol on Mass Loss for Mix M1.

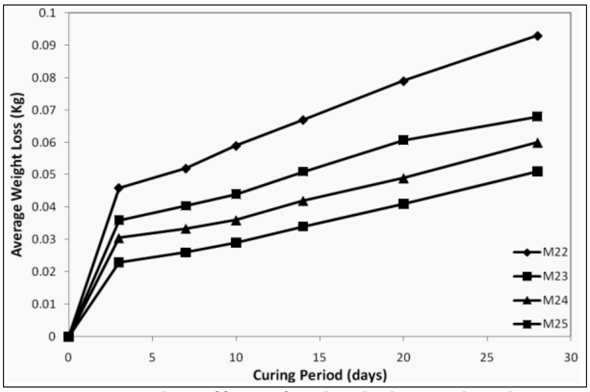

Figure (2) The Effect of Polyethylene-Glycol on Mass Loss for Mix M2.

3.2. Compressive Strength

The strength parameters of mixes M1 and M2 were compared using water curing and air curing at 7days, 14 days and 28 days. Self compact concrete cured internally using 0.3%, 0.5% and 1% PEG-400 attained more compressive strength than conventional concrete. The results of the compressive strength are represented in Table 5&6 and the graphical representations are shown in Figs. (3, 4 and 5). The compressive strength was found to increase up to 0.5% PEG400 and then decreased for M1 & M2. The increase in compressive strength was 17.17% at 0.5% of PEG 400 compared to plain concrete curing in air for M1, while the increase is 10.66% at 0.5% of PEG400 in case of M2. We note that the use of 0.3% and 0.5% Polyethylene-Glycol PEG400 gives an early resistance to the concrete at 7 days by 0.84% of the compressive strength of concrete in case of M1. Using the same proportions (0.3% and 0.5%) in the mixture M2 gives early resistance at 7 days by 78%, 82% respectively of the compressive strength of concrete.

Table (5) Compressive Strength of M1

Designation	Days MPa		
	7	14	28
M11	28.6	37.27	43.3
M12	27.88	38.67	43.14
M13	34.19	38.98	40.65
M14	42.48	47.57	50.55
M15	26.13	30.99	39.34

Table (6) Compressive Strength of M21

Designation	Days MPa		
	7	14	28
M21	23.28	29.49	33.42
M22	18.21	30.68	33.75
M23	28.52	33.84	36.3
M24	30.83	34.4	37.35
M25	17.66	26.31	28.75

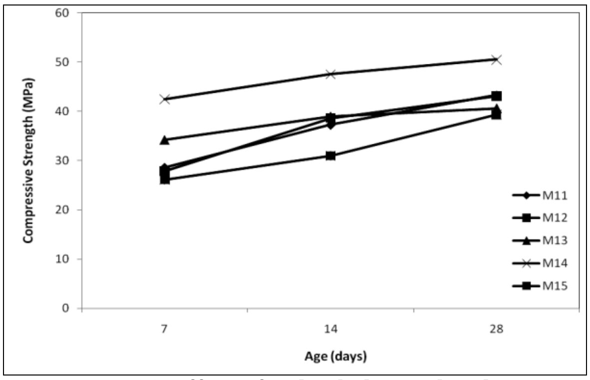

Figure (3) Effect of Polyethylene-Glycol on Compressive Strength for Mix M1.

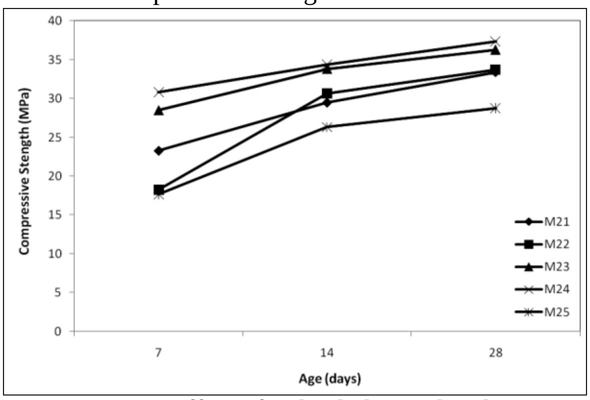

Figure (4) Effect of Polyethylene-Glycol on Compressive Strength for Mix M2

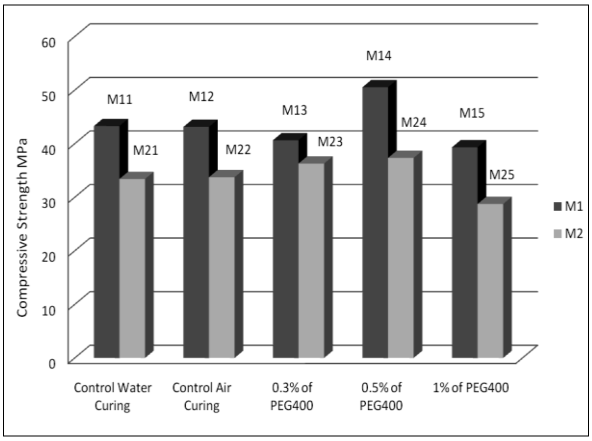

Figure (5) Comparison of Compressive Strength for self-curing concrete mixes and conventional concrete mixes

3.3. Splitting Tensile Strength

The results of the split tensile strength are represented in Table 7 and the graphical representation is shown in Figs. (6, 7and 8). The split tensile strength was found to increase at 0.5% PEG400 and then decreased for M1. In the case of M2 split tensile strength increased at 0.5% and then decreased. The increase in split tensile strength was 25.6% at 0.5% of PEG400 compared to plain concrete curing in air for M1, while the increase is 3.08% at 0.5% of PEG400 in case of M2.

Table (7) Splitting Tensile Strength of M1 & M2 Self Curing Concrete

Desig-nation	Days MPa			Desig-nation	Days MPa		
	7	14	28		7	14	28
M11	**3.66**	**4.52**	**4.81**	**M21**	**3.08**	**3.573**	**4.08**
M12	**2.83**	**3.887**	**4.055**	**M22**	**2.66**	**3.44**	**4.084**
M13	**3.795**	**4.215**	**4.059**	**M23**	**3.429**	**3.57**	**3.93**
M14	**3.601**	**4.917**	**5.094**	**M24**	**2.81**	**3.76**	**4.21**
M15	**3.42**	**3.79**	**4.12**	**M25**	**2.816**	**2.95**	**3.03**

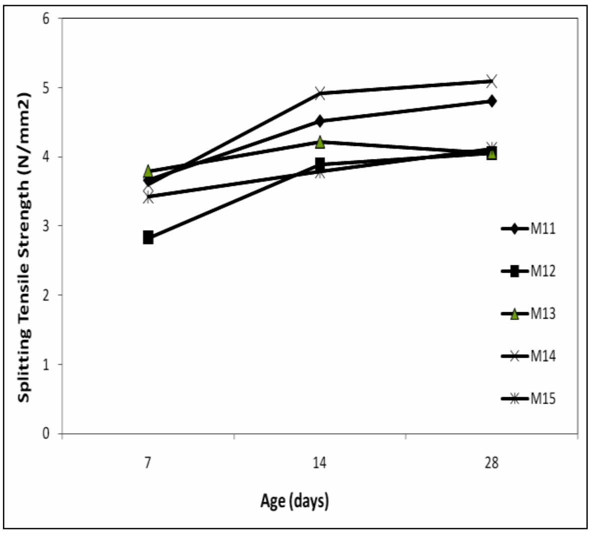

Figure (6) Effect of Polyethylene-Glycol Content on Splitting Tensile Strength for Mix M1

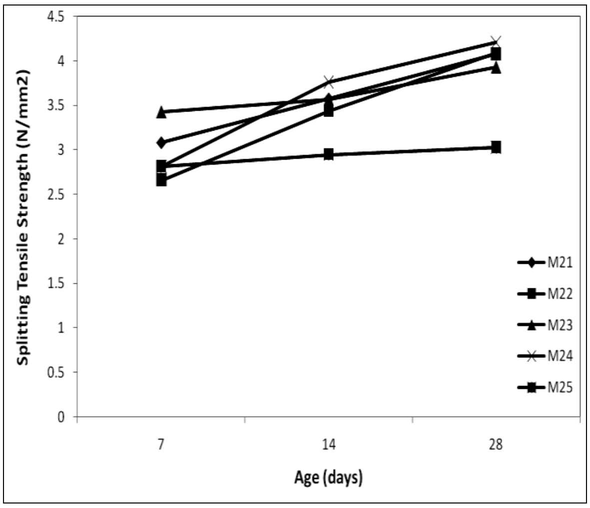

Figure (7) Effect of Polyethylene-Glycol Content on Splitting Tensile Strength for Mix M2

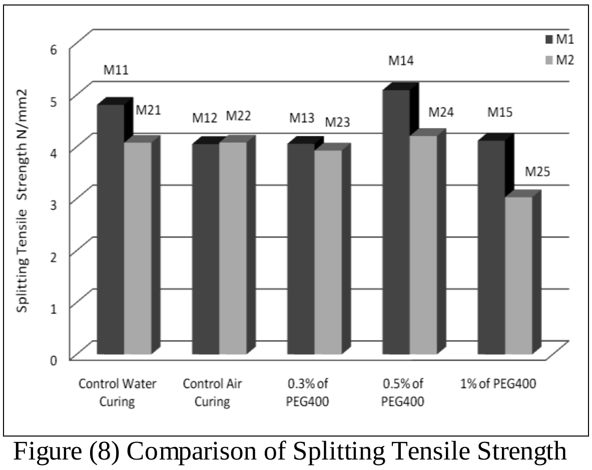

Figure (8) Comparison of Splitting Tensile Strength for Self-Curing Concrete and Conventional Concrete Mixes

3.4. Modulus of Rupture

The results of the modulus of rupture are represented in Table 8 and the Variation of Modulus of Rupture is shown in Fig 9. The modulus of rupture was found to decrease up to 0.5% PEG400 and then increased for M1. In the case of M2 modulus of rupture increased up to 0.5% and then decreased. The decrease in modulus of rupture was 13.5% at 0.5% of PEG 400 compared to plain concrete curing at air for M1, while the increase is 2.92% at 0.5% of PEG400 in case of M2 of concrete.

Table (8) Modulus of Rupture

No.	Designation	frup (MPa) at 28 days	
		M1	M2
1	Plain (Water Curing)	8.475	8.1
2	Plain (air Curing)	8.5	6.85
3	0.3% PEG	7.8	6.5
4	0.5% PEG	7.35	7.05
5	1% PEG	7.95	6.05

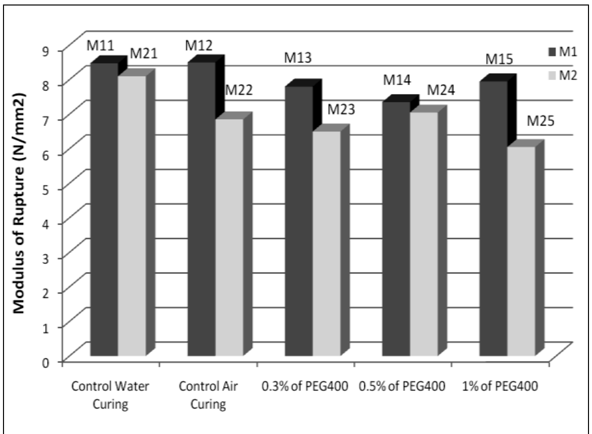

Figure (9) Comparison of Modulus of Rupture for Self-Curing Concrete and Conventional Concrete Mixes

3. Conclusions

1- In general Self Cured Concrete (SCC) gives better strength than Conventionally Cured once till 14 days, after that for 28 days results are almost the same for both concrete.

2-The optimum dosage of PEG400 self curing agents for maximum strengths (compressive, tensile and modulus of rupture) was found to be 0.5% for M1 & M2 concrete mixes.

3- For Mix M1 & M2 self-curing self compact concrete with 0.3% dosage PEG 400 shows least weight loss compare to other dosages.

4- Generally Water retention of concrete mixes incorporating PEG 400 is higher compared to conventional concrete mixes.

5- Using PEG400 with dosage 0.3%, 0.5% gives an early strength to the concrete at 7 days by 0.80% of the compressive strength of concrete.

6- Self curing concrete is the solution to many problems faced due to lack of proper curing, less labor and harsh environmental conditions in addition to hot and dries weathering conditions.

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