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Study and Review of Properties & Applications of Low Heat Cement

Shruti Bhimrao Jadhav

Rajarambapu Institute of Technology, Sakhrale – Walwa

E-mail: ShratiJadhav_1902043@litindia.edu

ABSTRACTS

The purpose of this study was to study and analyze the properties and applications of low heat cement. This research method is a qualitative description, which is supported by secondary data collection from literature, journals and other references. The results of this study show that the application of the latest technology in creating and applying low heat cement resulted in an increase in cement strength for buildings within the Australian standard AS3972. This is because the low heat change is achieved by reducing the content of C_3 S and C_3. It is a compound that develops the maximum heat of hydration and increases C_2 S.

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1. INTRODUCTION

Low Heat Cement is specially blended to provide a lower heat of hydration in concrete. This unique attribute makes it ideal for mass concrete pours where the rate of temperature rise and the maximum temperature achieved must be controlled in order to reduce the risk of thermal cracking. It is manufactured by modifying the chemical composition of normal Portland cement.

Hydration of cement is an exothermic action which produces large quality of heat. Crack formation in large body of concrete due to heat of hydration has focused the attention of the concrete technologists to produce a kind of cement which produces less heat or the same amount of heat, at a low rate during the hydration process. Cement having this property was developed in U.S.A. during 1930 for use in mass concrete construction, such as dams, where temperature rise by the heat of hydration can become excessively large. A low-heat evolution is achieved by reducing the contents of C_3 S and C_3 A which are the compounds evolving the maximum heat of hydration and increasing C_2 S. Chemical action of hardening will be reduced by reduction of temperature, which will further restrict the rate of evolution of heat.The rate evolution of heat will, therefore, be less and evolution of heat will extend over a longer period. Therefore, the feature of low-heat cement is a slow rate of gain of strength. But the ultimare strength of low-heat cement is the same as that of ordinary Portland cement. As per the Indian Standard Specification the heat of hydration of low-heat Portland cement shall be as follows:

7 days ---- not more that 65 calories per gm.

28 days ---- not more than 75 calories per gm.

Fig. 1. Concrete Dam Constructed by Low Heat Cement
(https://civil-online2010.blogspot.com [accessed on, 10/04/2021, 9.48am])

The specific surface of low heat cement as found out by air-permeability method is not less than 3200 sq. cm/gm. The 7 days strength of low heat cement is not less than 16 MPa in contrast to 22 MPa in the case of ordinary Portland cement. Other properties, such as setting time and soundness are same as that of ordinanry Portland cement (Reference: https://civil-online2010.blogspot.com)

Low heat cement also can be identified as the type of cement that generates low heat of hydration during its initial chemical reaction. According to the classification of cement by ASTM C150, these types of cement are classified under Type IV – Low Heat Hydration. Further, low heat cement also classified based on its performance by ASTM C1157 as Type LH – Low heat of hydration. Out of the four main components in the concrete, C_3 S and C_3 A are the main contributors to the heat generated in the hydration process. The amount of C_3 A are reduced in low heat cement and then the hydration process will be slow. As a result, the rise of the temperature will be limited.

Table 1. ASTM C 186 Heat of hydration for selected portland cements, calories per gram*

Type I cement			Type II cement			Type II (moderate heat) cement		Type III cement			Type IV cement			Type V cement	
No.	7 day	28 day	No.	7 day	28 day	No.	7 day	No.	7 day	28 day	No.	7 day	28 day	No.	7 day
1	82.0	—**	16	77.7	101.4	32	67.6	36	88.0	99.0	38	60.0	—	41	81.5
2	85.6	—	17	82.6	88.8	33	65.0	37	89.0	95.0	39	57.3	—	42	66.5
3	81.6	—	18	88.7	89.4	34	54.3				40	49.7	65.5	43	79.3
4	80.2	—	19	88.0	—	35	64.7							44	80.4
5	78.4	—	20	73.6	—									45	76.1
6	88.3	90.2	21	88.5	—									46	61.4
7	88.2	106.1	22	77.1	89.7										
8	87.7	93.5	23	87.3	—										
9	88.9	97.7	24	81.9	100.3										
10	76.4	91.7	25	88.3	99.4										
11	84.4	91.7	26	86.5	96.8										
12	84.4	98.5	27	79.5	—										
13	83.5	—	28	79.4	—										
14	79.5	—	29	80.0	—										
15	83.0	—	30	80.0	—										
			31	77.6	—										
Avg.	83.5	95.6	**Avg.**	82.3	95.1	**Avg.**	62.9	**Avg.**	88.5	97.0	**Avg.**	55.7	NM	**Avg.**	74.2
Max.	88.9	106.1	**Max.**	88.7	101.4	**Max.**	54.3	**Max.**	NM	NM	**Max.**	49.7	NM	**Max.**	81.5
Min.	76.4	90.2	**Min.**	73.6	88.8	**Min.**	67.6	**Min.**	NM	NM	**Min.**	60.0	NM	**Min.**	61.4

* This table is based on limited data provided by various testing laboratories and cement companies. The cements were tested between 1992 and 1996.
** No data available.
NM: not meaningful.
1 cal/g = 4.184 kJ/kg

Fig. 2. Heat of hydration table

(Reference: https://www.structuralguide.com/low-heat-cement/

[accessed on 11/04/2021, 2.15pm])

As indicated in the above table of ASTM C186, the average heat generated by the Type IV cement is low when compared with other types of portland cement.

2. METHOD

Clinker composition

Low heat Portland cement takes dicalcium silicate as the main mineral. The content is usually more than 40%. The content of Tricalcium aluminate is relatively low which no more than 6%. The free calcium oxide is less 1.0%.

Compressive strength

The early strength of low heat cement is low, but the late strength growth rate is fast.the minimum strength of low heat cement is 13.0 MPa at 7 days and 42.5 at 28 days. The following graph depict indicative compressive strength development for Low Heat Cement.

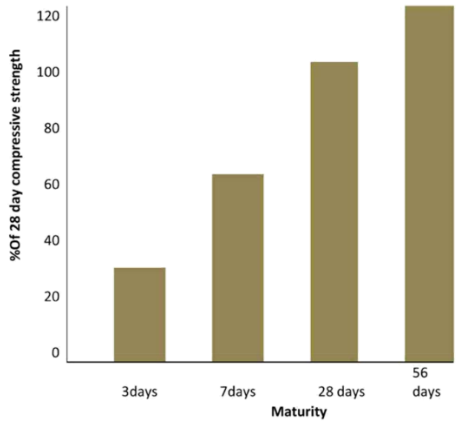

Fig. 5. daywise compressive strength

(https://www.cementaustralia.com.au/product/low-heat-cement [accessed on 11/04/2021, 2.45pm])

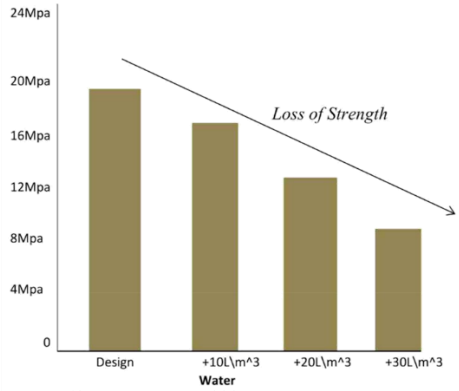

Fig. 6. Effect of excess water addition on concrete Compressive strength (https://www.cementaustralia.com.au/product/low-heat-cement [accessed on 11/04/2021, 3.15pm])

- Setting time

The initial setting time of low heat cement is 60 minutes (minimum) and the final setting time is 10 hours (max).

- Hydration heat

The hydration heat released by low heat Portland cement is low and the release process is gentle.

- Specific surface area: 250 m2/kg
- Strength grade: 42.5 (Reference: https://www.cementplantequipment.com)

Item	Standard Value
Specific Surface Area	250 m^2/kg Min
Initial Setting	60 minutes Min
Final Setting	12 hours Max
Compressive Strength at 7d	13.0 MPa Min
Compressive Strength at 28d	42.5 MPa Min
Breaking Strength at 7d	3.5 MPa Min
Breaking Strength at 28d	6.5 MPa Min
Heat of Hydration at 3d	230 KJ/kg Max
Heat of Hydration at 7d	260 KJ/kg Max

Fig. 4. Properties of Low Heat Cement

(https://theconstructor.org [accessed on 10/04/2021, 10.15am])

3. RESULTS AND DISCUSSION

Low Heat Cement Manufacturing Process

Low heat cement is manufactured by adjusting the mineral constituent, grinding fineness, and blending materials of ordinary Portland cement. It has a small amount of tricalcium aluminate and a high percentage of dicalcium silicate. Low heat Portland cement manufacturing process can be divided into five stages:

- Raw material cruching
- Raw material grinding
- Clinker calcination
- Clinker grinding
- Cement packing

At each stage, we need different production processes and various types of cement equipment.

Raw Material Crushing

In the raw material crushing process, cement crushers assist to crush cement raw material into a smaller size. The crushed materials are stored in a pre-homogenixation storage yard.

Fig. 7. Hummer Crusher (https://www.cementplantequipment.com./cement-application/low-heat-

cement-manufacturing/ [accessed on 11/04/2021, 3.20pm]).

Fig. 8. Jaw Crusher
(https://www.cementplantequipment.com./cement-application/low-heat-cement-manufacturing/ [accessed on 11/04/2021, 3.25pm])

Fig. 9. Fibrating Feeder
(https://www.cementplantequipment.com./cement-application/low-heat-cement-manufacturing/ [accessed on 11/04/2021, 3.35pm])

Fig. 10. Stacker and Reclaimer
(https://www.cementplantequipment.com./cement-application/low-heat-cement-manufacturing/ [accessed on 11/04/2021, 3.46pm])

Raw Material Grinding

70%-84% limestone, 10%-20% clay, 5%-10% sulfuric acid slag, and 1%-5% iron tailings are mixed in proportion and then fed into the raw mill for fine grinding.

Fig. 11. Cement Vertical Mill
(https://www.cementplantequipment.com./cement-application/low-heat-cement-manufacturing/ [accessed on 11/04/2021, 4.00pm])

Fig. 12. Raymond Mill
(https://www.cementplantequipment.com./cement-application/low-heat-cement-manufacturing/ [accessed on 11/04/2021, 4.15pm])

Fig. 13. Pulse Jet Bag Filter
(https://www.cementplantequipment.c

om./cement-application/low-heat-cement-manufacturing/ [accessed on 11/04/2021, 4.20pm])

Fig. 14. Cement Silo
(https://www.cementplantequipment.com./cement-application/low-heat-cement-manufacturing/ [accessed on 11/04/2021, 4.30pm])

Clinker Calcination

Cement raw meals should be calcined in a cement kiln at 1350°C to 1400°C for 30 to 45 minutes and then cooled by a cement cooler to obtain cement clinker. If we adopt the new dry cement production process, we should set preheater and precalciner before the kiln.

Fig. 14. Precalciner
(https://www.cementplantequipment.com./cement-application/low-heat-cement-manufacturing/ [accessed on 11/04/2021, 4.40pm])

Fig.16. Cyclone Preheater
(https://www.cementplantequipment.com./cement-application/low-heat-cement-manufacturing/ [accessed on 11/04/2021, 5.00pm])

Fig. 17. Cement Rotary Kiln
(https://www.cementplantequipment.com./cement-application/low-heat-cement-manufacturing/ [accessed on 11/04/2021, 5.10pm])

Fig. 18. Grate Cooler
(https://www.cementplantequipment.com./cement-application/low-heat-cement-manufacturing/ [accessed on 11/04/2021, 5.20pm])

Clinker Grinding

In this stage, the cement is ground in cement mills until reaches a standard fineness. During this process, it is

allowed to add an appropriate amount of admixtures (less than 1%) without damaging the performance of cement.

Fig. 19. Cement Ball Mill
(https://www.cementplantequipment.com./cement-application/low-heat-cement-manufacturing/ [accessed on 11/04/2021, 5.30pm])

Fig. 20. Cement Roller Press
(https://www.cementplantequipment.com./cement-application/low-heat-cement-manufacturing/ [accessed on 11/04/2021, 5.47pm])

Fig. 21. Cement Separator
(https://www.cementplantequipment.com./cement-application/low-heat-cement-manufacturing/ [accessed on 11/04/2021, 6.10pm])

Fig. 22. Belt Convevor
(https://www.cementplantequipment.com./cement-application/low-heat-cement-manufacturing/ [accessed on 11/04/2021, 6.20pm])

Cement Packing

Cement powder is usually stored in cement silos and then packed in bags by a cement packing machine.

Fig. 23. Cement Packing Maching
(https://www.cementplantequipment.com./cement-application/low-heat-cement-manufacturing/ [accessed on 11/04/2021, 6.32pm])

Low Heat Cemen Vs Moderate Heat Cement vs Low heat Slag Cement

There are three kinds of medium and low heat Portland cement: low heat cement, moderate heat cement, and low heat slag cement (containing 20%-60% blast furnace slag). They all have the characteristics of low hydration heat and are suitable for the construction of large structure.

Low Heat Cement	Moderate Heat Cement	Low Heat Slag Cement
Application: Hydration mass concrete engineering, high-performance concrete engineering, and other key engineering construction.	**Application:** Large-scale construction works and engineering required for wear resistance, such as dams, bridge beams, and nuclear power plants.	**Application:** Interior and underwater construction of large-scale structures.
Features: 1. Its hydration heat is low, which is more than 30% lower han that of ordinanry Portland cement with the same strength grade. 2. The early strength of low heat cement concrete is low, but its late strength is mush higher than the moderate heat cement concrete. And the 90-day strength is more than 10 MPa higher than ordinary Portland cement. 3. It has excellent mechanical properties, anti-cracking ability, and durability, as well as small dry shrinkage. The adiabatic temperature rise of low heat cement is 5-10°C lower than moderate heat cement and ordinary Portland cement.	**Features:** 1. The hydration heat of moderate heat cement is more than 15% lower than the ordinary Portland cement with the same strength grade. 2. Due to the low adiabatic temperature rise of the moderate heat cement concrete, the shrinkage cracks that may occur in the later cooling stage of the hardenes concrete can be avoided or reduced. 3. It has excellent long term strength and great chemoresistance.	**Features:** 1. The hydration heat of low heat slag cement is also low, mainly realized by adding mixed materials. 2. Low heat slag cement has low early strength, good performance, and low cost. It can make great use of industrial waste, such as blast furnace slag.
Ingredient: Ordinary Portland cement clinker, an appropriate amount of gypsum, and mixed materials.	**Ingredient:** Ordinanry Portland cement clinker, an appropriate amount of gypsum, and mixed materials. The content of C3S in moderate heat cement should be no more than 6% and free	**Ingredient:** Ordinanry Portland cement clinker, an appropriate amount of gypsum, and blast furnace slag (20%~60% by mass percentage). The content of C3A in low heat slag cement should be no more

Low Heat Cement	Moderate Heat Cement	Low Heat Slag Cement
	calcium oxide is less than 1.0%	than 8%, free calcium oxide is no more than 1.2%, and the magnesium oxide is less than 5%.
Strength grade: 42.5	**Strength grade:** 42.5	**Strength grade:** 32.5

(https://www.cementplantequipment.com/cement-application/low-heat-cement-manufacturing/)

Characteristics:

1. The amount of water required for hydration is low.
2. High workability is obtained as the concrete is fluidly in nature.
3. Good volume stabilisation.
4. Initial strength is low but the high growth rate of final strength.
5. More high technical strength of concrete.
6. Excellent impact erosion.
7. Excellent wear resistance.
8. Lower temperature upward value of heat insulation.
9. Super-high performance if chemical corrosion resistance.
10. Excellent resistance to drying shrinkage.
11. Good resistance ti rupture.

Low Heat Cement is compatible with:

- Chemical Admixtures for Concrete.
- Supplemenari Cementitious Materials for Use with Portland cement: **Fly ash, Slag- ground granuated from blast-furnace, Amorphous silica.** (reference: https://theconstructor.org)

Application of Low Heat Cement

1. To make the road and workroom surface of factories such as chemical plants and sulphuric acid factories.
2. Majorly used in constructing dams large footings, large raft slabs, wind turbine plinths.

Fig. 24. Construction of thermal plant using Low heat cement
(https://theconstructor.org [accessed on 12/04/2021, 7.45am])

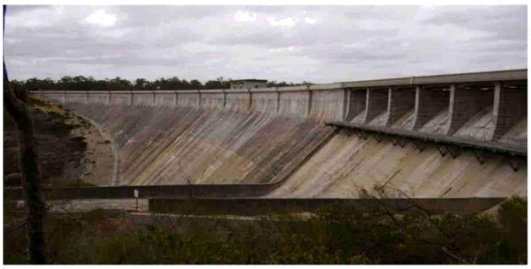

Fig. 25. Dam construction
(https://www.bing.com/images
[accessed on 12/04/2021, 8.00am])

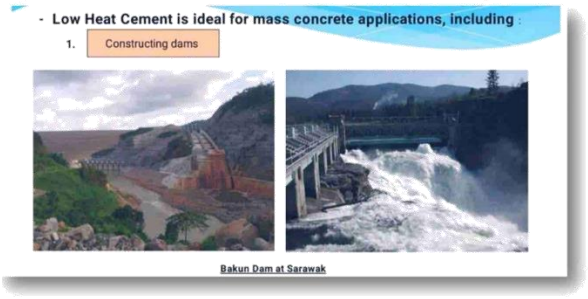

Fig. 26. Application of low heat cement
(https://www.scribd.com/presentation
/135373933/Low-Heat-Portland-Cement
[accessed on 12/04/2021, 9.00am])

Fig. 27. Application of low heat cement
(https://www.scribd.com/presentation
/135373933/Low-Heat-Portland-Cement
[accessed on 12/04/2021, 9.10am])

Fig. 28. Application of low heat cement
(https://www.scribd.com/presentation
/135373933/Low-Heat-Portland-Cement
[accessed on 12/04/2021, 9.27am])

Advantages and Disadvantages of Low Heat Cement

A. Advantages

1. Assist in minimising the potential for thermal cracking in thick concrete sections.
2. Improvised durability performance.
3. Excellent performances such as high final strength, sulphate corrosion resistance, good lasting properties, good resistance to rupture, anti-seepage.
4. Increased workability and pumpability with large pours in hydraulic engineering concrete and marine concrete works.
5. Significantly improved later-age concrete strength.
6. Resistant to sulphate attack on reinforcement majorly in concrete pipes.

B. Disadvantages:

1. Initial strength gained is lower than that of OPC concrete, but the final strength is same as that OPC.
2. This cement cannot be used in the cold weather conditions.
3. Cost of the cement is higher than that of Ordinary cement. (Reference: https://theconstructor.org)

Some Important Information

- Since the rise of the heat is less in the hydration process: the rice of core temperature, the temperature difference between the core and the surface and temperature gradient is reduced.
- Initial strength gain is slow but it gets strength with time and significant improvement in the strength is observed.
- Excellent resistance to the drying shrinkage.
- Excellent durability performance.
- High resistance to chemical attacks.
- These types of cement cannot be used n cold weather environments.
- The cost for the cement could be higher than other types of ordinary Portland ***cement*** (https://www.structuralguide.com/low-heat-cement/)

4. CONCLUSION

Recent technology delivers improved later-age concrete strength. When low heat cement is used in concrete significant strength development after 28 days may be achieved. The performance of this type of cement has been proven over many years in critical and complex engineering projects. Low heat cement is manufactured to comply with the requirements specified in Australian standard AS3972, for type LH Cement. It also complies with AS3972 REQUIREMENTS for type SR (sulphate resisting cement).

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