

كلية المستقبل الجامعة

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قسم هندسة تقنيات البناء والانشاءات

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Chemical composition of Portland cement

The primary materials used in Portland cement manufacture are mainly lime, Silica, alumina and iron oxide. These compounds interact with each other inside the oven to form more complex materials and compounds, and a small amount of non-united lime due to lack of time to combine with other compounds, and these chemical reactions continue inside the oven until the chemical equilibrium state is reached, and as a result, The burning product of clinker contains four main compounds as shown in the table below

التركيب الكيميائي	الرمز الكيميائي المختصر	اسم المركب	ت
$2 \text{ CaO} \cdot \text{SiO}_2$	C₂S	سليكات ثنائي الكالسيوم	١
$3 \text{ CaO} \cdot \text{SiO}_2$	C₃S	سليكات ثلاثي الكالسيوم	٢
$3 \text{ CaO} \cdot \text{Al}_2\text{O}_3$	C₃A	ألومينات ثلاثي الكالسيوم	٣
$4 \text{ CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$	C₄AF	ألومينات الحديد رباعي الكالسيوم	٤

These Symbols are obtained by means of the oxide symbols used by the cement chemists.

الرمز المختصر	الرمز الكيمياوي	الأكاسيد
A	Al_2O_3	أوكسيد الألمنيوم
C	CaO	أوكسيد الكالسيوم
F	Fe_2O_3	أوكسيد الحديد
S	SiO_2	أوكسيد السليكون

Di-Calcium Silicate, C2S

This compound is characterized by its **slow reaction speed** and **gives little heat during the reaction**, initial bearing to **resist compression is weak** , but its **final bearing is good**.

Tri-Calcium Silicate, C3S

This compound is characterized by its **moderate reaction speed**, and it liberates a **good amount of heat during the reaction**,

Initial and final bearing is good, and this compound was form with C2S is about **(60-80)%** of Portland cement.

Tri-Calcium Aluminate, C3A

This compound is characterized by its **rapid reaction and release a large amount of heat during the reaction.** **initial bearing compression is good , but its final bearing is weak.** and this compound is a concern قلق, due to its great interaction with Salt, Which leads to cement damage تلف او اضعاف الاسمنت.

Tetra-Calcium Aluminate Ferrite, C4AF

It represents a group of oxides similar in properties to previous oxides, and reacts with water at a speed lower than C3A

Water compounds are **more stable than C3A** compounds and **less stable than** hydrated calcium silicate compounds. The hydration temperature is higher than that generated by C2S and less than the other compounds and is found by **(5-10)%** of the weight of cement and has little impact on it.

- In addition to the four major compounds, there are other compounds with a very low percentage:

1. أوكسيد المغنيسيوم (MgO).

2. أوكسيد البوتاسيوم (K_2O).

3. أوكسيد الصوديوم (Na_2O).

4. أوكسيد المنغنيز (Mn_2O_3).

5. أوكسيد التيتانيوم (TiO_2).

6. ثالث أوكسيد الكبريت (SO_3).

7. الفسفور (P_2O_5).

In addition to the main compounds mentioned above, there exist minor compounds, such as **MgO**, **TiO₂**, **Mn₂O₃**, **K₂O** and **Na₂O**. Two of the minor compounds are of particular interest: K₂O and Na₂O, known as the **alkalis (about 0.4-1.3% by weight of cement)**. They have been found to react with the reactive silica found in some aggregates, the products of the reaction causing increase in volume leading to disintegration **تهشم او تحطم** of the concrete. Increase in the alkalis percentage has been observed to affect the setting time and the rate of the gain of strength of cement.

- **SO₃** form low percentage of cement weight. **SO₃** comes from the gypsum added (2-6% by weight) during grinding of the clinker, and from the impurities الشوائب in the raw materials, also from the fuel الوقود used through firing process.
- **Iraqi specification no. 5 limited max. SO₃ by 2.5% when C3A ≤ 7%, and by 3% when C3A > 7%.**

- **MgO**, present in the cement by **1-4%**, which comes from the magnesia compounds present in the raw materials. Iraqi specification no. 5 limited max. **MgO by 5%**, to control the expansion resulted from the hydration of this compound in the hardened concrete. When the magnesia is in amorphous form, it has no harmful effect on the concrete.
- **Other minor compounds such as TiO₂, Mn₂O₃, P₂O₅** represent **< 1%**, and they have little importance.

- The percentage of the main composition of cement can be calculated according to the Bogue equations, based on the assumption that the reactions reached the chemical equilibrium state

$$C_3S = 4.07 (\text{CaO}) - 7.6 (\text{SiO}_2) - 6.72 (\text{Al}_2\text{O}_3) - 1.43 (\text{Fe}_2\text{O}_3) - 2.85 (\text{SO}_3)$$

$$C_2S = 2.87(\text{SiO}_2) - 0.754 (C_3S)$$

$$C_3A = 2.65 (\text{Al}_2\text{O}_3) - 1.69 (\text{Fe}_2\text{O}_3)$$

$$C_4AF = 3.04 (\text{Fe}_2\text{O}_3)$$

Usual Composition Limits of Portland Cement

Oxide	Content, %
CaO	60-67
SiO ₂	17-25
Al ₂ O ₃	3-8
Fe ₂ O ₃	0.5-6
MgO	0.5-4
Alkalis (as Na ₂ O)	0.3-1.2
SO ₃	2.0-3.5

Typical compound composition in ordinary Portland cement

Compound	Content, %
C_3S	54
C_2S	17
C_3A	11
C_4AF	9

• **Loss on Ignition (L.O.I)**

It is the loss of the cement sample weight when it expose to the **red temperature (at 1000°C)**. It shows the extent of carbonation and hydration of free lime and free magnesia due to the exposure of cement to the atmosphere. Also, part of the loss in weight comes from losing water from the gypsum composition. The maximum loss on ignition permitted by Iraqi specification no. 5 is 4% by weight.

هو الفقدان في وزن النموذج بعد التسخين الى درجة الحرارة الحمراء (Red Heat) 1000 م°،
ويعبر عن مقدار الكربنة (Carbonation)، وعن عملية الأماهة (Hydration Process) التي
تحدث للجير الحر (Free Lime) والمغنيسيا الحرة الموجودين في السمنت نتيجة خزن السمنت

لفترة طويلة (Prolonged Story)، أو نتيجة تعرضه للظروف الجوية، كما وأن جزءاً صغيراً من
الفقدان أثناء الأيقاد ناتج عن فقدان الماء الداخل في تركيب الجبس وتحدد المواصفات القياسية
البريطانية نسبة الفقدان أثناء الأيقاد من 3% في المناخ المعتدل، الى 4% في المناخ الأستوائي، أما
المواصفات القياسية العراقية فتحدد نسبة الفقدان للسمنت البوتلاندي الأعتيادي والسريع التصلب
بـ 4% كحد أقصى.

• Insoluble residue

It is that part of cement sample that is insoluble in HCl. It comes from the unreacted silica, to form soluble cement compounds diluting in this acid, largely arising from impurities in gypsum. The maximum insoluble residue permitted by Iraqi specification no. 5 is 1.5% by weight.

• هي ذلك الجزء من نموذج السمنت الغير قابل للذوبان في حامض الهاييروكلوريك، وتنشأ بصورة رئيسية من السليكا غير المتفاعلة لتكوين مركبات السمنت الذائبة في هذا الحامض، لذا فإن المجلفات غير الذائبة تعبر عن مدى أكمال التفاعلات الكيماوية في داخل الفرن، والمواصفات القياسية العراقية تحدد نسبة المجلفات غير الذائبة ب ١.٥ % من وزن السمنت كحد أقصى

*THANK YOU FOR
YOUR ATTENTION*

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