

23 February 2016
Lecture 3 - Gypsum

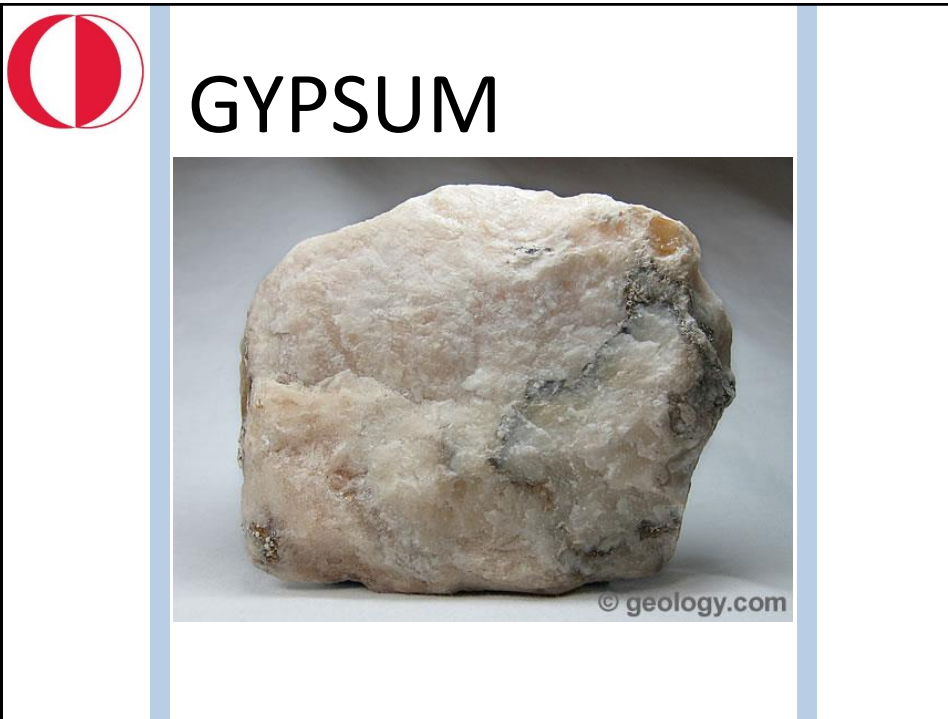
CE 344

Materials of Construction

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CE 344 – Tentative Outline			
Week	Dates		Topic
1	22-Feb	26-Feb	1. Introduction to materials of construction 2. Gypsum
2	29-Feb	4-Mar	3. Lime
3	7-Mar	11-Mar	4. Portland cement
4	14-Mar	18-Mar	(1 st Lab around these dates)
5	21-Mar	25-Mar	
6	28-Mar	1-Apr	5. Pozzolans
	Specific date TBA		1 st MIDTERM EXAMINATION
7	4-Apr	8-Apr	6. Aggregates
8	11-Apr	15-Apr	(2 nd Lab around these dates)
9	18-Apr	22-Apr	7. Concrete
10	25-Apr	29-Apr	(3 rd Lab around these dates)
11	2-May	6-May	
12	9-May	13-May	
	Specific date TBA		2 nd MIDTERM EXAMINATION
13	16-May	20-May	8. Ferrous metals, alloys and concrete reinforcement
14	23-May	27-May	9. Polymers
			10. Clay bricks
(*) The detailed course schedule is available at the course web page.			
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Gypsum

- In nature : Gypsum Rock
- Pure gypsum rock is a hydrous calcium sulfate:

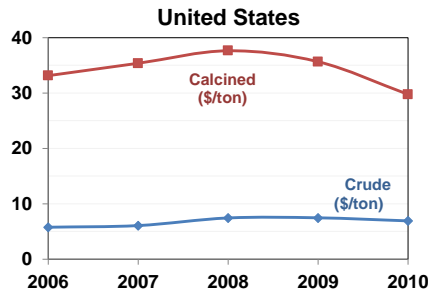
$$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$$

Calcium sulfate water
- Impurities
 - MgO, Al₂O₃, Fe₂O₃, SiO₂, CaCO₃, MgCO₃...



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Gypsum mining



	(1000 tons)	2012	Reserves
1	China	48,000	NA
2	Iran	14,000	NA
3	Spain	11,500	NA
4	Thailand	10,000	NA
5	United States	9,900	700,000
6	Japan	5,700	NA
7	Italy	4,100	NA
8	Mexico	3,850	NA
9	Russia	3,100	NA
10	Australia	3,000	NA
11	Turkey	3,000	NA
12	Brazil	2,800	230,000
13	India	2,750	69,000
14	France	2,300	NA
15	Saudi Arabia	2,300	NA
16	Canada	2,200	450,000
17	Germany	2,050	NA
18	United Kindom	1,700	NA
19	Algeria	1,650	NA
20	Argentina	1,200	NA
21	Poland	1,200	55,000
22	Other countries	14,900	NA
	World (rounded)	150,000	Large

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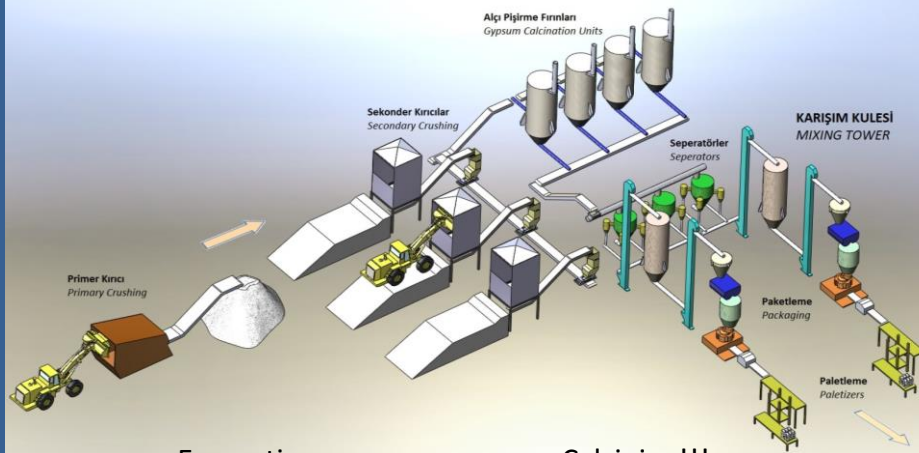
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Production Steps of Gypsum



- Excavating
- Crushing
 - (~25 mm diameter)
- Grinding
- Calcining!!!
- Cooling
- Pulverizing
- Marketing in bags

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2014 Prices in Turkey

- Gypsum plaster for machine application
 - Applied directly over bricks, concrete, aerated concrete bloks and bims blocks
 - For each 1 cm, 10-11 kg/m²
 - 35 kg/bag → 161 TL/ton
- Saten plaster
 - For each 1 mm, 1 kg/m²
 - 25 kg/bag → 279 TL/ton
- Gypsum plaster with Perlite for hand application
 - Applied directly over bricks, concrete, aerated concrete bloks and bims blocks manually
 - For each 1 cm, 9-9.5 kg/m²
 - 35 kg/bag → 154 TL/ton

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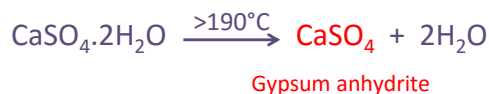
Calcination of Gypsum

- Gypsum rock when heated to 100-190°C loses ¾ of its water:



(This is low burning process called as **INCOMPLETE CALCINATION**.)

- When calcination is carried out at temperatures above 190°C all water is removed:



(This is high-burning process & **COMPLETE CALCINATION**.)

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Gypsum

Mineral	Gypsum	Gypsum hemihydrate (plaster of paris)	Anhydrite
	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	$\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$	CaSO_4
<i>Chemical composition, wt%</i>			
Lime (CaO)	32.6	38.6	41.2
Sulfur Trioxide (SO ₃)	46.5	55.2	58.8
Water of crystallization (H ₂ O)	20.9	6.2	0.0
<i>Density, g/cm³</i>			
	2.24	2.63-2.76	2.97

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Potential development

- Factors that must be considered when evaluating a gypsum resource for potential development:
 - Purity
 - Proximity to market area
 - ⑩ because gypsum has a low unit value
 - Transportation
 - ⑩ shipment of raw and finished materials by truck, train, ship, or barge
 - Fuel and utilities
 - ⑩ a source fuel for calcination, an infrastructure for electricity
 - Water

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Calcination of gypsum

Q

- How much plaster of paris (gypsum hemihydrate) can be obtained by calcination of 1 ton of pure gypsum rock?

(Ca: 40, O:16, S: 32, H:1)

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Calcination of gypsum

Q

- 500 kg of a gypsum rock is calcinated; and 320 kg of pure plaster of paris is obtained. Determine whether the gypsum rock is suitable for commercial use?

(At least 70 % $\text{CaSO}_4 \cdot 2\text{H}_2\text{O} \rightarrow \text{OK!}$) (Ca: 40, O:16, S: 32, H:1)

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These reactions are reversible...

- Both of these products form gypsum rock by recombining with water :



Very rapid,
hardens in a
few minutes!!



A little
slower!

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Kilns for Gypsum Calcination

- Calcination process is carried out in two types of kilns:

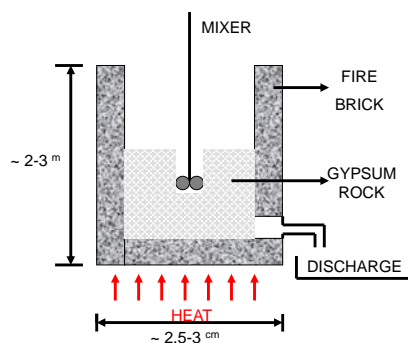


- Kettle Kilns*

- pulverized raw material

- Rotary Kilns*

- pulverized or crushed rock as raw material; obtained product is more homogeneous)



~Φ2.5m x L20 m



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Late 1800s...

- A commercial process to slow the setting time, thereby allowing widespread use of finishing plaster.



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Using sand in gypsum plaster



- The mixture of gypsum and water (gypsum paste) is too sticky to be troweled.
- Besides, it shows excessive shrinkage upon drying.
- The use of sand eliminates the stickiness of the gypsum paste, reduces the shrinkage, and provides economy since sand is cheaper than gypsum.

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Ultimate strength of gypsum

- The water/gypsum ratio:
 - If high → amount of water leaving the mixture by evaporation will be high → more voids will be left behind → lower strength
 - 0.6 = ~ the lowest w/g ratio at which the material is plastic enough to be shaped
- Amount of sand:
 - Higher → lower the strength of gypsum mortar
 - Strength (2/3 sand + 1/3 gypsum) = 60% Strength (pure)

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Lightweight aggregates instead of sand

- Sometimes, lightweight aggregates such as expanded perlite are used instead of sand for the preparation of plasters.
 - The use of lightweight materials leads to a lighter weight for plaster.
 - Thus, it is easily lifted and applies on the walls and ceilings, and it results in lower dead load on them.
 - Plasters made by using lightweight materials have higher sound absorption.

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Water in gypsum plaster

Q

- When mixing gypsum plaster, what happens if you add too much water?

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Gypsum plasters

- Obtained by Incomplete Calcination ($\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$)
- 1. **Plaster of Paris** : formed by incomplete calcination at 100-190°C. (No extra admixtures)
 - Setting time ~5-20 min;
 - used for sculpturing, ornamental work, small repair work as it expands on hardening, producing a clear impression of the mold

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Gypsum plasters

- Obtained by Incomplete Calcination ($\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$)
- 2. **Hard Wall Plaster** : Plaster of Paris + Admixtures (0.2-2% by weight: Glue, clay, hair...)
 - Setting time ~ 1 hr, compressive strength ~ 7 MPa
 - Admixtures result in increased plasticity & setting time & reduced shrinkage
 - Can be used for plastering walls; production of prefabricated structural units; masonry bricks & blocks
 - Wall plasters are usually applies in two coats (total thickness $\sim 1.5 - 2.5$ cm: 70-75% sand, 15-25% gypsum, and some additive materials to control the working qualities, setting time, etc.

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Gypsum plasters

- Obtained by Complete Calcination (CaSO_4)
- 1. **Flooring Plaster** : CaSO_4 with no impurities
- 2. **Hard Finish Plaster** : ($\text{CaSO}_4 + \text{Al}_2(\text{SO}_4)_3$); ($\text{CaSO}_4 + \text{Na}_2\text{B}_4\text{O}_7$)
 - Setting time $\sim 1-16$ hrs; compressive strength > 7 MPa
 - Can be used for producing prefabricated units, masonry bricks & blocks & flooring & pavement bricks & tiles.



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Gypsum vs. Fire



- Gypsum often serves as a fire proofing material even though its strength is destroyed by long continuous heat.
- Heating gypsum liberated water vapor, which helps hinder the spread of fire.
- It forms a powder covering the surface which acts as an effective insulator.

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Gypsum vs. Moisture



- Gypsum products tend to disintegrate when exposed to moisture → it should not be used for exterior work & for moist interiors : (NON-HYDRAULIC)

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Gypsum as a by-product

■ Phospogypsum

- Major by-product of phosphoric acid production

■ Flue gas desulfogypsum (FDS)

- Obtained from the desulfurization of combustion gases in coal burning power plants (Harmful SO_2 gas is turned into $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)

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Next lecture...

■ Lime

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