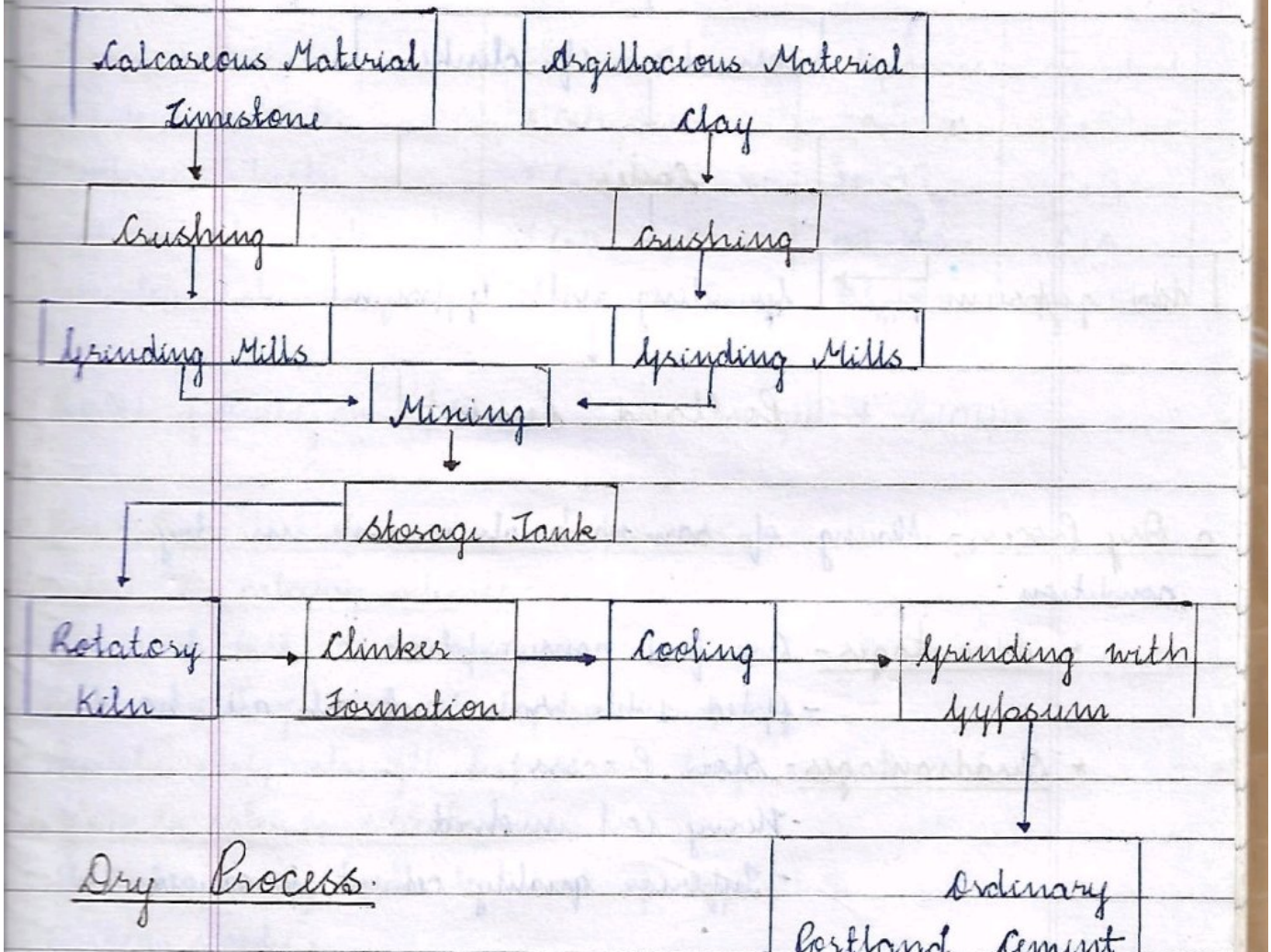
- Manufacturing of OPC - Manufacturing of OPC is done in main 3 steps -

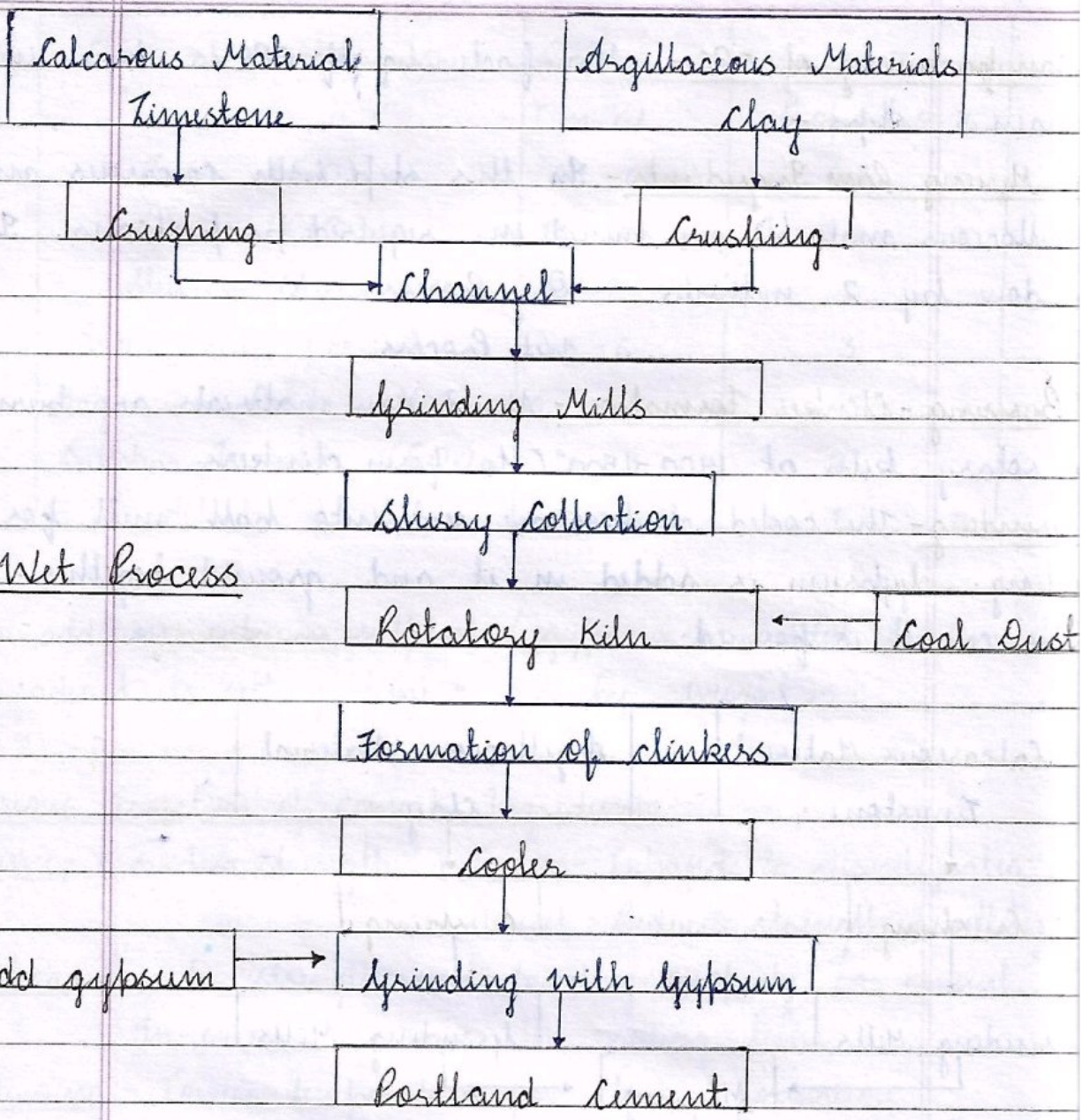
a. Mining Raw Ingredients - In this step both calcarous and argillaceous materials are mined in squired proportions. It is done by 2 methods - Dry Process
Wet Process.

b. Burning - Clinker Formation - Mixed raw materials are burned in rotary kiln at 1400 - 1500°C to form clinkers.

c. Grinding - The cooled clinkers are sent into ball mill for cooling. Gypsum is added in it and ground together. Thus cement is formed.



Dry Process.



a. Dry Process - Mixing of raw materials is done in dry condition.

* Advantages - Less fuel consumption.
  - Opted when raw materials are hard.
* Disadvantages - Slow Process.
  - Heavy cost involved
  - Inferior quality cement produced.

b. Wet Process - Mixing of raw materials in wet condition by mixing water - slurry is formed.

Advantages - Uniform mixing - homogenous mixture formed.
- Economical in long run.
- Good quality cement produced.
- Less time consumed.

- Disadvantages - Pure water without impurities is required.

* Compounds of cement - The compounds formed in cement at the formation of clinkers are :- Bogue's compounds.

Compound name	Chemical Formula	% by mass	Symbol
Tri calcium silicate	$3CaO \cdot SiO_2$	30-50	C_3S
Di calcium silicate	$2CaO \cdot SiO_2$	20-45	C_2S
Tri calcium aluminate	$3CaO \cdot Al_2O_3$	08-12%	C_3A
Tetra calcium alumino ferrite	$4CaO \cdot Al_2O_3 \cdot Fe_2O_3$	06-10%	C_4AF

- Products formed on hydration - C-S-H gel + $Ca(OH)_2$

* Basic Properties of cement compounds -

a. C_3S - Tri calcium silicate -
- Forms at last - 30-50 %.
- Best cementing material. Hydrates rapidly.
- Develops early strength & produces large hydration heat.

b. C_2S - Di calcium silicate -
- Hydrates slowly with less heat of hydration.
- Hardens slowly.
- Do not give early strength. provides ultimate strength.

- Proportion - 20-45%
- Form 3rd at the kiln.
- Good resistance to sulphate attacks.

c. C_3A - Tri calcium aluminate -

- First compound to react when water is mixed.
- Cause initial setting and early strength of cement.
- Weak against sulphate attack.
- Generates large heat of hydration.

d. C_4AF - Tetra calcium alumino ferrite -

- Formed first at the kiln.
- It hydrates rapidly and contributes a little strength.
- It is a neutral material and has no work in cement.

* Tests for OPC -

a. Field Test of cement -

- Should be uniform grey in colour.
- Felt smooth when mixed in cement.
- Should not contain any lumps. If there, should be crushed by hand.
- Felt cool when hand is kept in a bag of cement.

b. Laboratory Testing -

* Fitness Test - It is used to check if cement is grinded properly. For this 100 g cement is sieved through IS sieve no. 9 (90 microns) for 15 minutes. The residue is then weighed. It should not more than 10% of its weight.

* Consistency Test - It is used to determine the % of water required for preparing cement paste, for other tests. This is performed by Vicat's apparatus.

• Penetration in Vicat's apparatus should be 33-35 mm.
Then, water absorption, $P = (W_2 \times 100) / W_1$

* Initial and Final setting time test - This test is also performed by Vicat's apparatus. The procedure is same as in consistency test. Initial setting time needle and final setting needle are used for test.

* Soundness Test - Cement should not undergo any change in volume after setting. Mortar / concrete is liable to expand and crack.
Le-Chatlier apparatus is used for this purpose. Cement water paste is moulded in it and boiled for 3 hours. It should not show a expansion more than 10 mm.

* Compressive Strength test - Cement sand mortar of 1:3 is prepared and is moulded into cubes and tested after 3 & 7 days of curing.

• Properties of Cement -
a Fitness - It is used to test the fineness of cement. Finer cement offers a larger surface area for hydration and hence results in early gain of strength. But too much fine cement results to cracking of cement.

b. Setting Time -

* Initial setting time - The time at which cement loses its plasticity. It is important for mixing, transporting etc..
* Final setting time - The time at which cement becomes hard enough to bear a certain amount of load.

c. Soundness - Cement should not go any change in volume (large amount) after setting. Unsoundness of cement is caused due to presence of free lime in cement. It hydrates very slowly, expands and leads to cracking of cement. It can be reduced by :-
- limiting MgO to less than 0.5%.
- fine grinding of raw materials and thoroughly mixing.

d. Compressive strength - It is most important property of cement

e. Specific gravity - It is generally calculated in design mix. It is generally 3.15 for ordinary portland cement

f. Heat of Hydration - The reaction between cement and water is termed as hydration of cement. During hydration, heat is released, which is termed as heat of hydration.

* Different types of cement - (as per IS codes)

a. Ordinary Portland Cement - It is most important and widely used cement. In India, it is available in 3 grades 43, 53 and 33 which determine their compressive strengths. Its manufacture is decreasing all over the world, due to its properties.