Unit 19 · Cement

HARDER PRACTICE QUESTIONS

Full marks 35

Write your answers on separate paper. Show your working. Molar masses (g/mol): Ca 40.08, C 12.01, O 16.00, Si 28.09, H 1.008.

1 From limestone to clinker: where the mass goes [6]

a. A plant makes clinker that is 65% CaO by mass, all of it from pure limestone, $CaCO_3$. The other 35% of the clinker comes from clay; assume the clay loses nothing in the kiln. [4]

i. What mass of limestone is needed for 1 tonne of clinker? (1)

ii. What mass of CO_2 does that limestone give off in the kiln? (1)

iii. What share of the dry raw meal is limestone? The unit says CaO is 60–67% of cement but limestone is "about three-quarters" of the raw mix. Explain why both are right. (2)

b. Nepal had 23 plants that make their own clinker and 42 that only grind clinker into cement (the Nepal Manufacturers' Association's count, 2023). Use your answers above to explain why a plant that makes clinker is built next to its limestone quarry, while a grinding plant can be built near the buyers. [2]

2 Fuel or rock: Nepal's cement CO_2 [7]

a. Nepal used about 8 million tonnes of cement in 2024. Take 0.51 t of CO_2 from the limestone for every tonne of clinker (the question above). Take OPC as 95% clinker and 5% gypsum, and PPC as 65% clinker, 30% fly ash and 5% gypsum. [3]

i. How much CO_2 would the limestone alone give off if all 8 million tonnes were OPC? And if all were PPC? (1)

ii. By what fraction does choosing PPC cut the CO_2 from the limestone, and how much is that in all? (1)

iii. A plant manager says: "The CO_2 from the fuel won't fall by anything like that much, since PPC goes through the same mills as OPC." Is he right? Explain. (1)

b. [4]

i. A speaker says: "Nepal has hydroelectricity to spare. Run every kiln on electricity instead of coal and Nepali cement will be carbon-free." Judge the claim, using your answers above. (2)

ii. If PPC saves so much CO_2 and costs less, why not make all of Nepal's cement PPC, with even more fly ash? Give two reasons from the unit. (2)

3 The price of water in the wet process [5]

a. In the wet process, the raw materials are fed to the kiln as a slurry with 35% water by mass. Take the dry raw meal for 1 tonne of clinker as 1.5 t, 2.3 MJ to evaporate 1 kg of water, and 25 MJ of heat from 1 kg of coal (a typical value). [3]

i. How much water goes into the kiln for each tonne of clinker, and how much heat goes in evaporating it? (2)

ii. Udayapur Cement was rated at 800 tonnes a day: take that as 800 tonnes of clinker a day. How much more coal a day would it burn by the wet process than by the dry, counting the evaporation alone? (1)

b. What did the wet process get in return for all that fuel? Say how a modern dry plant gets the same thing another way, and how it saves heat that a slurry kiln spends. [2]

4 Gypsum belongs in the mill [5]

i. To save a grinding step, an operator suggests adding the 4% gypsum to the raw meal **before** the kiln, instead of grinding it in with the clinker afterwards. Predict what the cement would be like on a building site, and explain. (2)

ii. One plant's clinker contains 6% tricalcium aluminate and another's 12%. Which plant should grind in gypsum near the top of the usual 3–5%, and why? (1)

iii. On a site, mortar from one batch of cement stiffens within a few minutes of mixing. Which compound in the cement is reacting, and what is probably wrong with that batch? Why can't the mason put it right by adding more water and mixing again? (2)

5 Concrete doesn't dry hard [7]

a. A 50 kg bag of OPC contains 55% tricalcium silicate (C_3S, Ca_3SiO_5) and 20% dicalcium silicate (C_2S, Ca_2SiO_4). They hydrate as the unit shows: [4]

$$2\,Ca_3SiO_5 + 6\,H_2O \rightarrow 3\,CaO\cdot 2SiO_2\cdot 3H_2O + 3\,Ca(OH)_2$$

$$2\,Ca_2SiO_4 + 4\,H_2O \rightarrow 3\,CaO\cdot 2SiO_2\cdot 3H_2O + Ca(OH)_2$$

i. What mass of water do these two compounds in one bag take up chemically when they have fully reacted? (2)

ii. What mass of calcium hydroxide do they release? Which of the two releases more per kilogram? (2)

b. i. A mason says: "Concrete hardens by drying, so splashing water on a new roof slab only slows it down." Use your answers to judge the claim. (2) [3]

ii. Which needs to be kept wet for longer, a slab of OPC or one of PPC? Explain with the calcium hydroxide. (1)

6 Two bags on the site [5]

An engineer tests two cements, X and Y, from bags whose labels were torn. One is OPC and the other PPC. She makes standard mortar cubes of each, and a large insulated block of concrete of each to measure how much its middle warms up while it sets.

	3 days	7 days	28 days	90 days	Rise in temperature of the block
X: strength (N/mm^2)	23	33	47	52	45 °C
Y: strength (N/mm^2)	16	25	42	55	32 °C

i. Which is OPC and which is PPC? Give two pieces of evidence. (1)

ii. Could X be sold as OPC 43? As OPC 53? A worker says Y is "grade 42". Comment. (1)

iii. Which would you choose for each job, and why? (2)

- A 2 m thick concrete foundation for a hydropower plant's powerhouse.
- Precast concrete beams in a factory, whose molds must be reused after 3 days.

iv. A supervisor says: "Y is weaker, so it is the worse choice for the foundation." Answer him from the table. (1)