

Problem 1.1: solution

What are the possible mixtures of these two rocks that would meet the chemical criteria for a raw material for this manufacturing process?

First let us test the two rocks in their pure states to see if they are suitable without mixing (Tab. 1)

Tab. 1 Suitability of the two rocks, unmixed, for making Portland cement.

Parameter	Requirement	Red Beds	Evaluation	Malm	Evaluation
SiO ₂	15 - 25%	23.10	Good	0.85	Bad
Al ₂ O ₃	3 - 8.5 %	4.90	Good	0.39	Bad
Fe ₂ O ₃	0 - 4%	1.40	Good	0.13	Good
CaO	35 - 42%	35.60	Good	52.96	Bad
MgO	max 5	0.51	Good	1.80	Good
SO ₃	max 3.5	0.01	Good	0.06	Good
CaO / SiO ₂	1.25 à 2.5	1.54	Good	62.31	Bad
SiO ₂ / Al ₂ O ₃ +Fe ₂ O ₃	2 à 4	3.67	Good	1.63	Bad
Al ₂ O ₃ / Fe ₂ O ₃	≥ 2	3.50	Good	3.00	Good

In conclusion, the argillaceous limestone of the Red Beds is suitable by itself. The Malm limestone, however, is not satisfactory: it contains too much CaO and not enough Al₂O₃ or SiO₂. In other words, this limestone is too pure; it does not contain enough clay.

Now let us test by iterations the proportion of the Malm that can be added to the Red Beds to create a mixture that meets the requirements. Using a spreadsheet, we gradually increase the proportion of Malm in the mixture until we reach the limit for one of the requirements. The calculation (Tab. 2) shows that we can meet the manufacturing criteria by incorporating 30% Malm. This proportion is the maximum because it is equivalent to a CaO/SiO₂ ratio of 2.48; the maximum is 2.5.

Tab. 2 Calculation of a mixture of 70% Red Beds and 30% Malm.

Composition	Red Beds (wt. %)	Malm (wt. %)	Mixture 70/30	Requirement	Verdict
SiO ₂	23.10	0.85	16.43	15 - 25%	Good
Al ₂ O ₃	4.90	0.39	3.55	3 - 8.5 %	Good
Fe ₂ O ₃	1.40	0.13	1.02	0 - 4%	Good
CaO	35.60	52.96	40.81	35 - 42%	Good
MgO	0.51	1.80	0.90	max 5	Good
SO ₃	0.01	0.06	0.03	max 3.5	Good
CaO / SiO ₂	1.54	62.31	2.48	1.25 to 2.5	At the limit
SiO ₂ / Al ₂ O ₃ +Fe ₂ O ₃	3.67	1.63	3.60	2 to 4	Good
Al ₂ O ₃ / Fe ₂ O ₃	3.50	3.00	3.48	≥ 2	Good
				Overall	At the limit

In conclusion, all mixtures that contain between 0% and 30% Malm limestone are thus technically suitable for the manufacture of Portland cement.

Identify other criteria specific to the site that may affect the choice of mixture.

Other criteria that may influence the choice between the Red Bed quarry and a mixture:

Aesthetic criteria

The Red Bed quarry is much more visible from the Rhône Plain than the Malm limestone quarry. Thus aesthetically it would be advantageous to limit the exploitation of the Red Bed by integrating the maximum of Malm limestone in the mixture.

Slope stability criteria

The Red Bed quarry has already resulted in a high rocky slope. In terms of slope stability, it would be wise to decrease exploitation in this quarry.

Geomaterials exploitation criteria

A decision to quarry the Malm limestone would make it possible to develop an aggregate industry because the limestone is pure and it can be used for concrete or bituminous coatings, for example, in addition to the cement industry.

Water protection criteria

The map shows that there is a spring at the base of the Malm limestone. This spring is obviously of karst origin. If the spring water is used for human consumption, quarrying above the spring will probably be illegal because of the presence of a groundwater protection area around the spring.

This last criterion, linked to the fact that the maximum proportion of limestone in the mixture remains rather low, leads to the conclusion that the most reasonable solution is to exploit only the Red Beds.