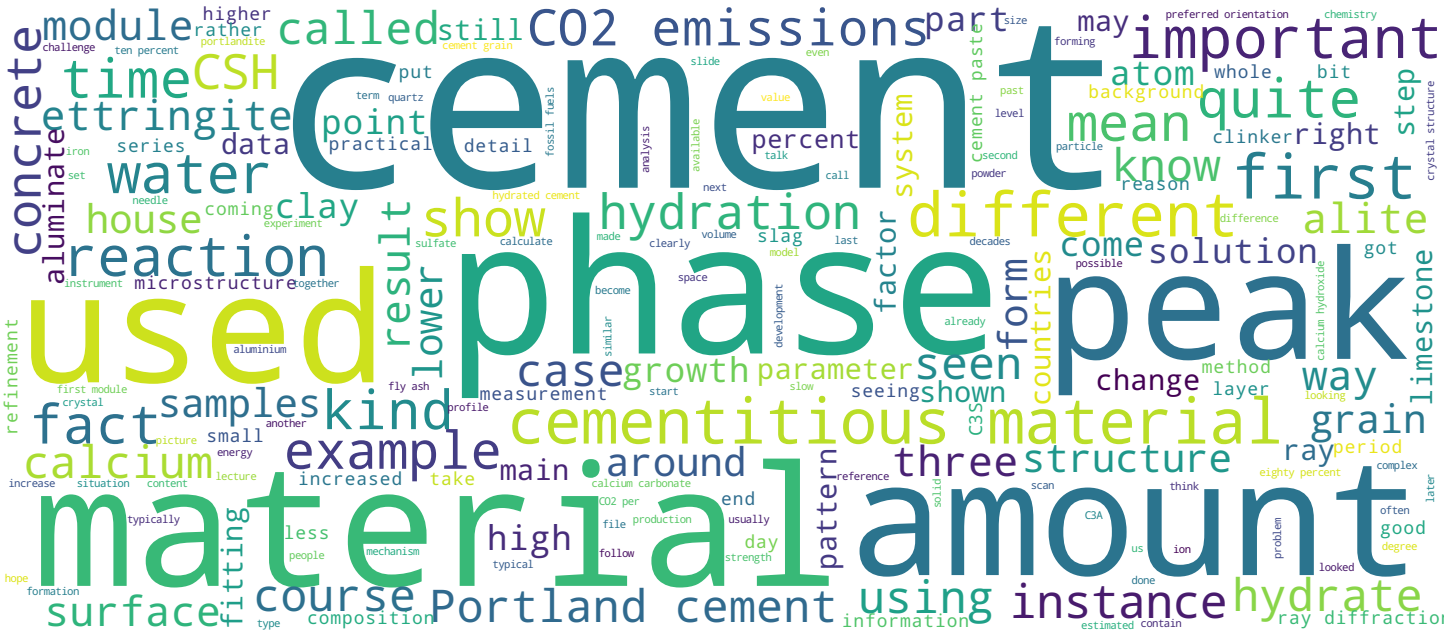
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Introduction 1: Context

Cement Chemistry and Sustainable Cementitious Materials

Professor Karen Scrivener, FREng



Search MOOC

Video

Outline

- Context
- CO_2 footprint

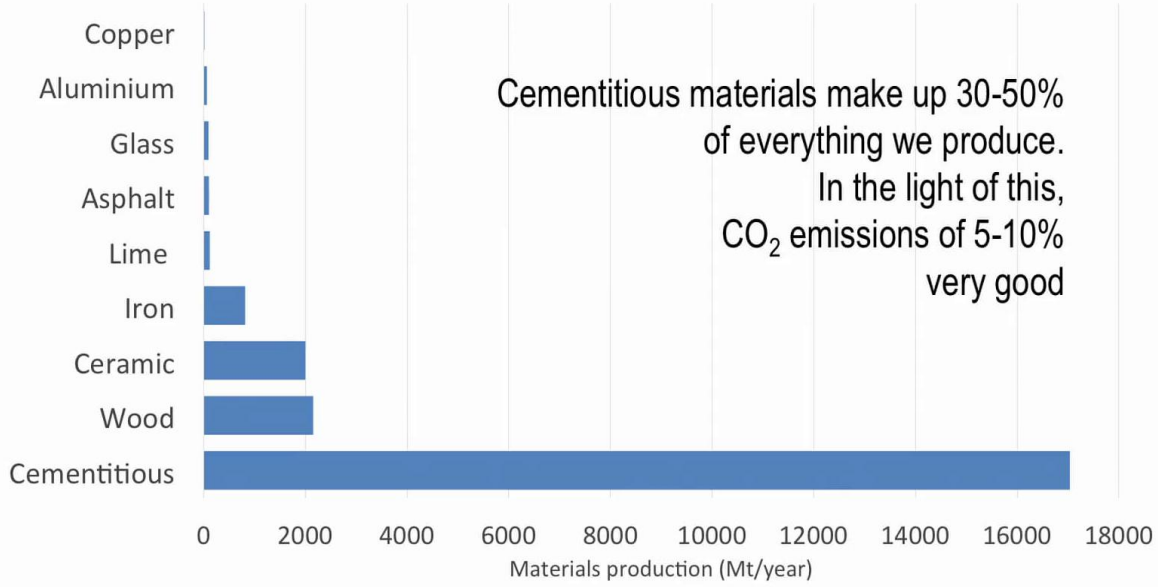
So hello and welcome to this series on cement chemistry for sustainable cementitious materials. In this series of modules, we are going to look at the cement chemistry and how this helps us to understand the sustainability of these very important materials. Most of the modules should be really understandable to anybody with a fairly basic knowledge of high school chemistry. In the first module, we are going to look at the overall context. We are going to look at the role of cementitious material in the world today and what are the origins of their CO2 footprint.

Notes

Summary

0m 04s

Cement based materials cannot be replaced



Now in this first slide, we can see the overwhelming dominance of cementitious materials They make up between thirty to fifty percent of everything we produce. Probably about fifty percent of solid materials and thirty percent if we include things like fossil fuels. And in the light of that the fact that they are responsible for CO2 emissions of around five to ten percent is a very good ratio. But more importantly, we can really see that this just would no way be possible to replace cementitious materials with alternatives at any meaningful level. For example, if we look at the amount of wood produced worldwide, this is between ten and fifteen percent the amount of cementitious materials and already it is estimated that this amount of wood is beyond the limits of sustainability that is to say we are cutting down more trees than we are planting. So while this may be a nice option in Europe or North America, it is really not practical for the many people who need to be housed in countries like China, India, Africa and South America.

Notes

Summary

0m 46s

Concrete is an environmentally friendly material

Material	MJ/kg	$kgCO_2/kg$
Cement	4.6	0.83
Concrete	**0.95**	**0.13**
Masonry	3.0	0.22
Wood	8.5	0.46
Wood: multilayer	15	0.81
Steel: Virgin	35	2.8
Steel: Recycled	9.5	0.43
Aluminium: virgin	218	11.46
Aluminium recycled	28.8	1.69
Glass fibre composites	100	8.1
Glass	15.7	0.85

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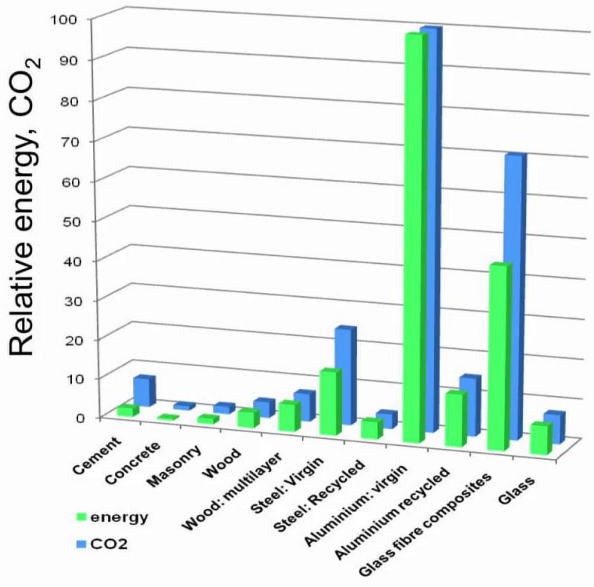
Hammond G.P. and Jones C.I
2008 Proc Instn Civil Engineers
www.bath.ac.uk/mech-eng/sert/embodied/



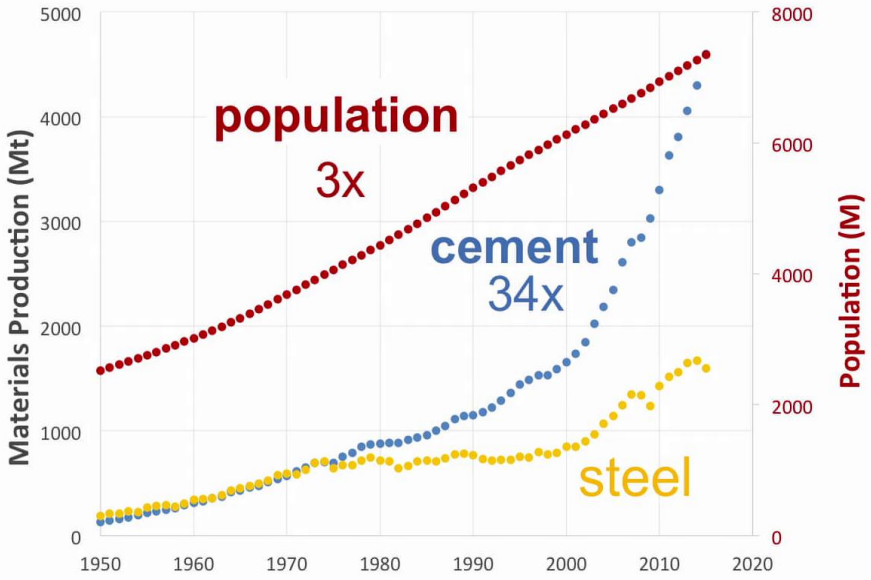
This slide here really shows how the environmental footprint of concrete is very low and we should talk about concrete because concrete is the final material we really use. Cement is the precursor and that is roughly about ten percent of cement in concrete. On the right here I have normalised these figures compared to the highest which is aluminium. You can see very vividly just how much energy and CO2 you can save by recycling aluminium and I hope after seeing this you don't throw your coke can in the bin anymore. But concrete is really extremely low, lower than almost all other materials. Of course this is just on a weight basis. When you put this into a structure, it becomes more complicated, we are not going to go into that here. But generally, even in that situation concrete still comes out very strongly as an environmentally friendly material.

Notes

Summary

2m 03s

Growth in cement use in last 70 years



The amount of cement we are using has increased very, very dramatically in the past few decades. Since 1950, the population has increased about three fold and at the same period the amount of cement we use has increased by about thirty four times. In recent decades this is really being driven by the development in China and we should not view this negatively because this development has lifted a lot of people out of poverty. It has provided them with decent homes, with roads, railways to get around and everything like that. But we certainly cannot imagine that this growth in demand for cement is going to slow down because there are many, many other parts of the world where people still haven't have decent housing or transportation systems.

Notes

Summary

3m 06s

5-10% in perspective

- CO_2 footprint of a house for a family (3 people) lasting 50 years:
  - 10-20 tonnes cement = ~150 kgCO_2/yr = ~**12** kg/ month

- Driving a car, 10,000 km /yr = 1000 kg CO_2/yr = ~**90** kg/m (7.5x)

Finally what we do with our lives and the CO2 produced is a question of choices. And here again if we decide to build a house, we make maybe a house for a family of three people, This will typically take about ten to twenty tons of cement and last for about fifty years. So we can calculate from that that the CO2 to do with your materials in your house is about twelve kilograms a month. Now if you're driving a car, which you almost certainly are, that same family of three will probably drive at least ten thousand kilometres a year and then they will be consuming fossil fuels which will be producing about ninety kilograms of CO2 per year. Seven or eight times more than the materials in their house.

Notes

Summary

3m 58s

5-10% in perspective

But what about the food you eat?

Meat eaters
5-7 kg/day

Vegetarians
3-4 kg/day

If those 3 people went from medium meat-eaters to vegetarian for just 2-3 days per month this would save the CO_2 needed for the concrete in the house!

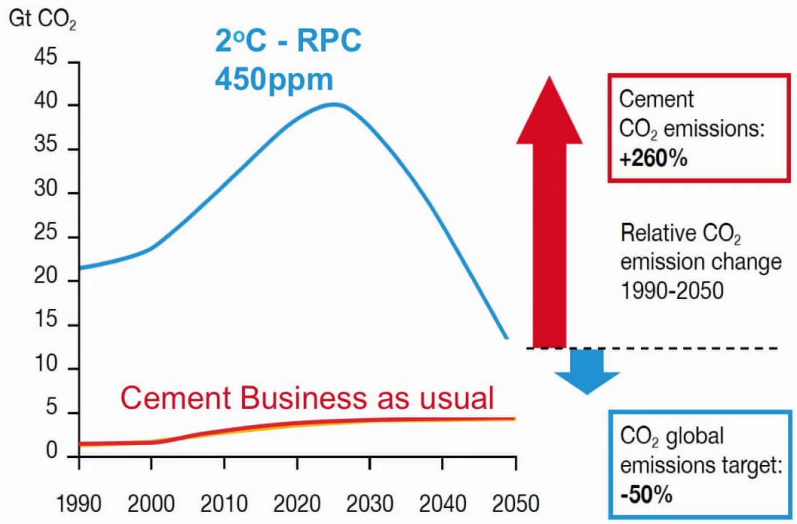
But we should also reflect on our other choices in life for example the food we eat. Here you can see for a very meat intensive diet the associated CO2 production would be around five to seven kilograms of CO2 per day. Whereas a vegetarian diet is much lower at around three to four kilograms of CO2 per day And so if we calculate for the same imaginary family of three that they went from eating meat to being vegetarian, maybe for just two or three days a month, this would be equivalent to saving all the CO2 that they needed to build their house. So rather than just blaming the producers of these materials, we have to think about what we are doing in our lives and what we choose to do that produces CO2.

Notes

Summary

4m 51s

But what if we do nothing?



Based on A blueprint for a climate friendly cement industry. WWF-Lafarge 2008

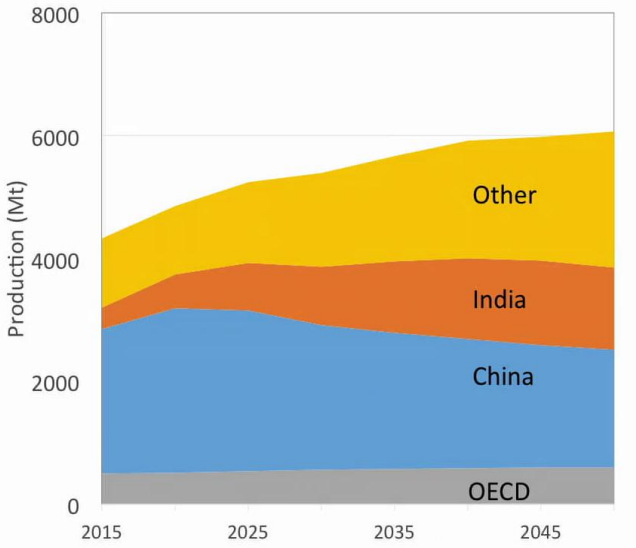
OK there is no reason for complacency because if we did nothing about the CO2 footprint of cementitious materials, we could end up in a situation like this. Here we see the blue line is the trajectory that has been estimated we should try to meet if we are to restrict global warming to this two degrees temperature rise. Whether we are going to do that or not is another question, but that is the trajectory of overall global emissions if we are going to do that. If we achieve that blue line and we did nothing about cement, then the emissions from the production of cement and cementitious materials will follow the red line. And we will see that by 2050 we would end up in a situation where cementitious materials would be responsible for something like thirty percent of world CO2 emissions, which is clearly unacceptable.

Notes

Summary

5m 41s

Forecast growth



We need solutions for people in developing countries

So where is the consumption of cement taking place? What we see here is the distribution of cement we use around the world. And only about ten percent of cement used is taking place in O.E.C.D. countries And in these countries, it is forecast that demand will really stay pretty much constant. More than ninety percent of consumption is taking part in the developing world, particularly in China which has been very dominant over the past two decades. It has been estimated in the last three years China produced more concrete than was produced in the whole of North America in the twentieth century. And many other countries, like India in particular, are looking to follow this development path to provide decent houses for their people, decent rail systems and decent road systems. And this will inevitably mean that the growth in use of cement is going to increase.

Notes

Summary

6m 39s

How to meet this challenge sustainably

Solutions need to be:

- Practical,
  usable by unskilled workers
- Economically viable

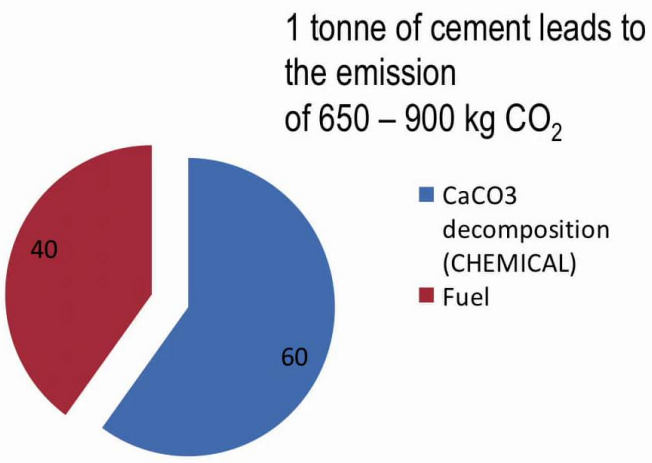
So if we are going to meet this challenge of the growing demand for cement, we need solutions which are first of all practical, they can be used by unskilled workers and this shows you the kind of typical situation you can have for mixing concrete - the example is from India - and also economically. Now you know cement is an incredibly cheap material, in most of Europe you can buy a ton of cement for less than one hundred euros for a whole ton. In many developing countries though the prices are actually higher even though the incomes are lower so it is very important that we have solutions which are really economically viable for these countries where there is this huge need for building infrastructure and housing etc.

Notes

Summary

7m 39s

Origins of CO_2 emissions in cement production



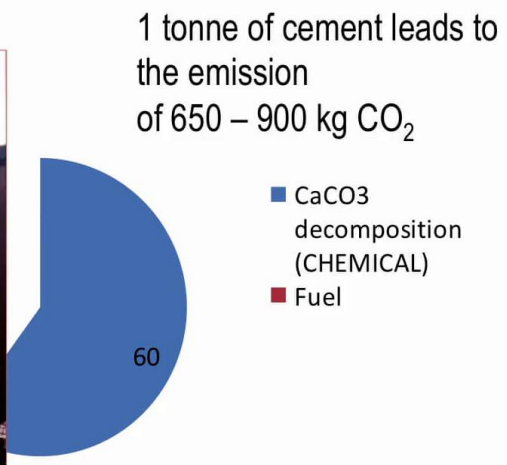
So let's look at where these CO2 emissions are coming from. Unlike most other industrial processes, only a minority of the CO2 emissions are coming from the energy consumption. Producing cement is a high temperature process, you are going up to temperatures of 1450 or so and this does take energy but it is still the minor amount.

Notes

Summary

8m 29s

Origins of CO_2 emissions in cement production



A cement kiln as we see here looks like a fairly unsophisticated type of instrument. But this is in fact not true because in the past few decades there has been very dramatic improvement in the amount of energy needed to produce cement.

Notes

Summary

8m 55s

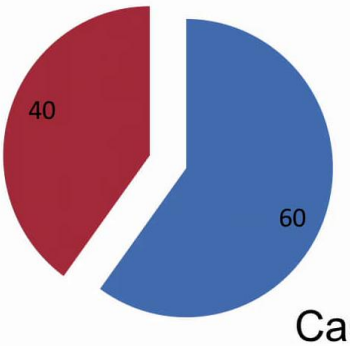
Origins of CO_2 emissions in cement production

The production process is highly optimised up to around 80% of thermodynamic limit.

It is estimated that **< 2%** further savings can be made here

Use of waste fuels, which can be **> 80%** reduces the demand for fossil fuels

1 tonne of cement leads to the emission of 650 – 900 kg CO_2



$CaCO_3 \rightarrow CaO + CO_2$

Limestone 80% of raw material

And it is really a state of the art equipment now, the production process is highly optimized, up to nearly eighty percent of the thermodynamic limit, which, as those of you who will study thermodynamics will know, is very close to the maximum you can achieve. Another factor which is important is that rather than using fossil fuels, which used to be the dominant means in the past, nowadays we can use a wide variety of waste fuels. So for example off cuts from producing furniture, old car tires, many many different kind of waste can be burnt in a cement kiln and in many parts of Europe, plants are using more than eighty percent of waste fuels. So this is a very efficient tool for valorising waste materials. So if we are going to make improvements we need to turn to the other side to this sixty percent of the equation and this sixty percent, this comes from the breakdown of calcium carbonate into calcium oxide and CO2. Calcium carbonate, this is in fact limestone which is eighty percent of the raw material used to make cement. Now the fact we have this chemical CO2 means that if we are going to reduce this, then this has implications for the chemistry of the cement and that means it has implications for the whole way it behaves in use etc which of course is a bit of a challenge.

Notes

Summary

9m 14s

Summary

- Importance of cement as a material
- Good environmental impact
- Origins of CO_2 emission

So what are we seeing in this lecture? Well we have seen how important cementitious materials are, how they make up by far the overwhelming majority of all the materials we used and therefore cannot be replaced by other materials. We have seen that in fact the environmental footprint from these materials is in fact quite low and we have looked at where the CO2 emissions come from and we have seen that most of the CO2 emissions come from the chemical breakdown of limestone, that is calcium carbonate and therefore we can't really imagine to do much about CO2 emissions by for example looking at alternative energies. So in the next lecture we are going to go into more detail about why the chemistry of cement is as it is. So I look forward to seeing you next time and I hope you have enjoyed this first module.

Notes

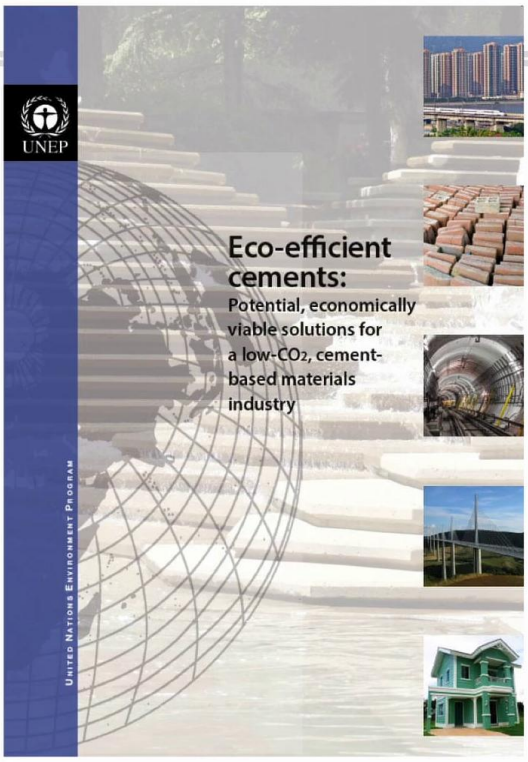
Summary

10m 54s

Where to find out more

Download at

http://lmc.epfl.ch/files/content/users/184559/files/2016-UNEPReport-Complete4.pdf



If you want to find out more, then this publication “Eco-efficient cements” which we published in November 2016, gives you a very good background to all the aspects I will tackle in this first module.

Notes

Summary

11m 45s