ENGINEERING MATERIALS FOR SUSTAINABILITY- CV0424

UNIT – 1

DEPARTMENT OF CIVIL ENGINEERING

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INDUS UNIVERSITY

Introduction, planet equivalent, carbon cycle

CONTENT

- SUSTAINABLE DEVELOPMENT
- ECOLOGICAL FOOTPRINT
- GLOBAL HECTARE
- PLANET EQULVALENT
- EARTH OVERSHOOT
- CARBON CYCLE

WHAT IS SUSTAINABLE DEVELOPMENT?

- It can defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

ECOLOGICAL FOOTPRINT

- Ecological footprint accounting measures the demand on and supply of the nature.

- The Ecological Footprint tracks the use of six categories of productive surface areas: cropland, grazing land, fishing grounds, built-up land, forest area, and carbon demand on land.

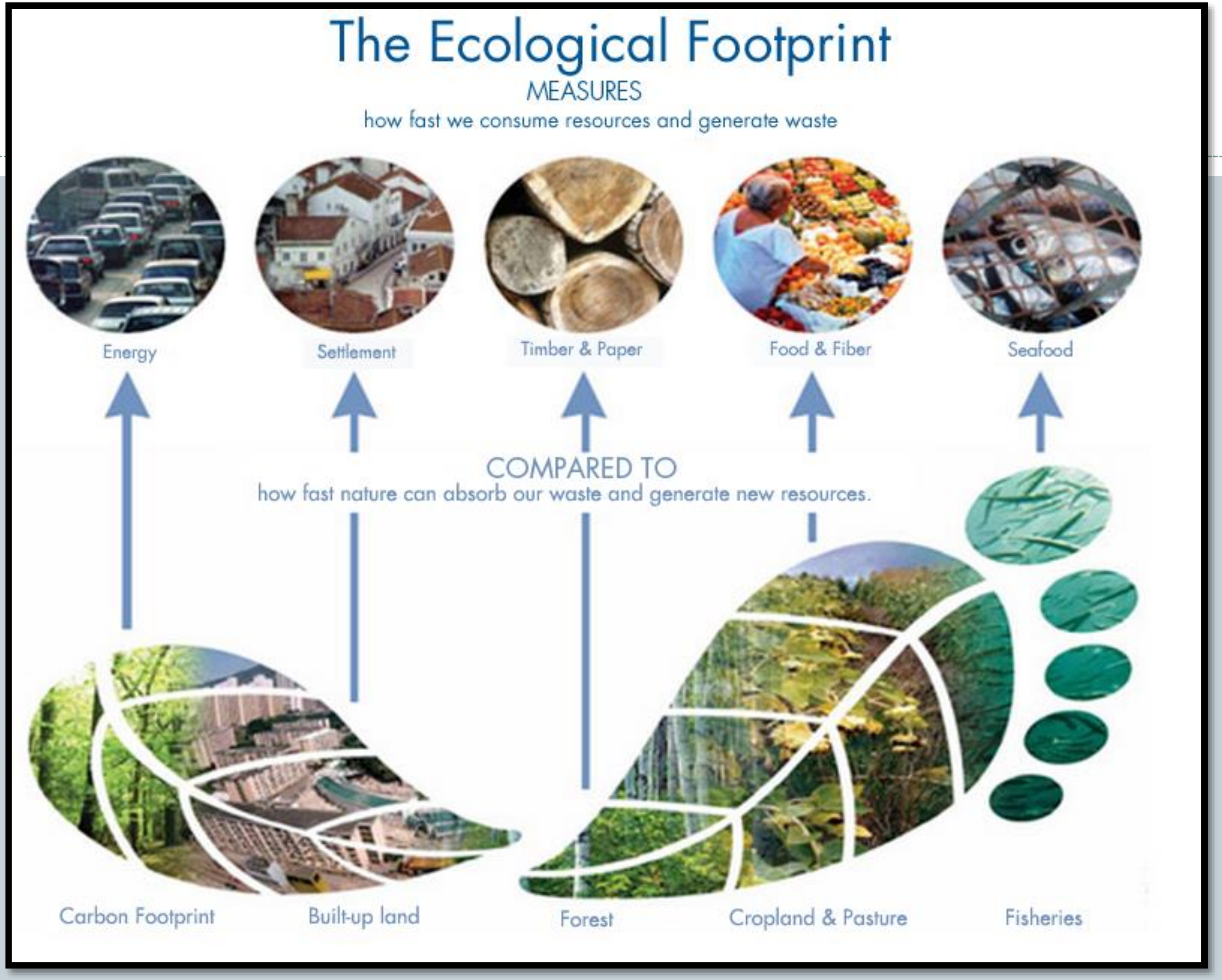
- It is expressed in global hectares [gha].

DEMAND SIDE

- On demand side it measures the ecological assets that a given population requires to produce the natural resources it consumes and to absorb its waste, especially carbon emission.

SUPPLY SIDE

- On the supply side, a city, state or nation's **bio capacity** represents the productivity of its ecological assets (including cropland, grazing land, forest land, fishing grounds, and built-up land). These areas, especially if left unharvested, can also absorb much of the waste we generate, especially our carbon emissions.


The Ecological Footprint
MEASURES
how fast we consume resources and generate waste
Energy
Settlement
Timber & Paper
Food & Fiber
Seafood
COMPARED TO
how fast nature can absorb our waste and generate new resources.
Carbon Footprint
Built-up land
Forest
Cropland & Pasture
Fisheries

- The accounting system also tracks the supply of nature: it documents how much biologically productive area is available to provide these services. [bio-capacity].

- Therefore, these accounts are able to compare human demand against nature's supply of bio-capacity.

GLOBAL HECTRE [GHA]

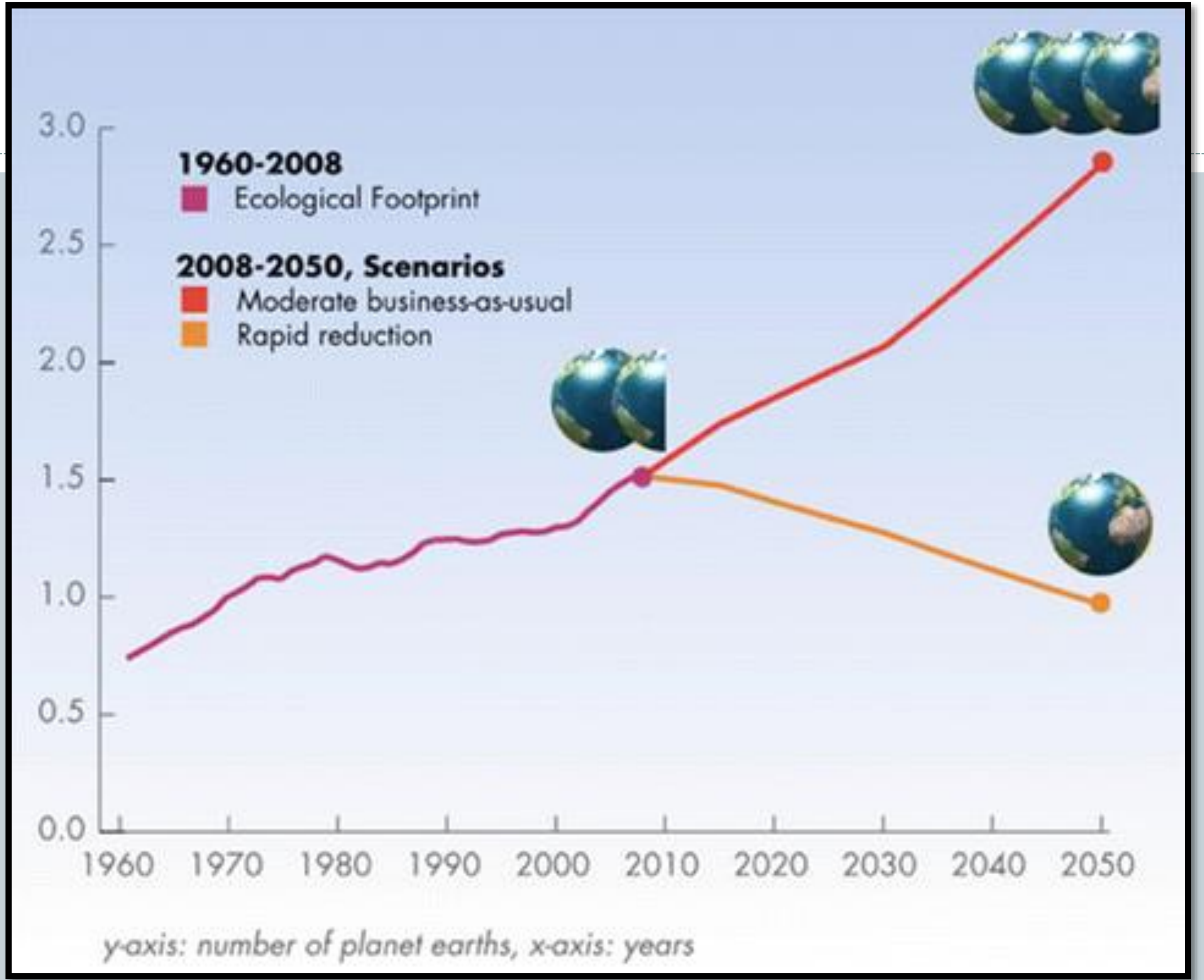
- Global hectares are the accounting unit for the Ecological Footprint and Bio-capacity accounts.

- The global hectare is normalized to the area-weighted average productivity of biologically productive land and water in a given year.

- Because world productivity varies slightly every year, the value of a gha may change slightly every year.

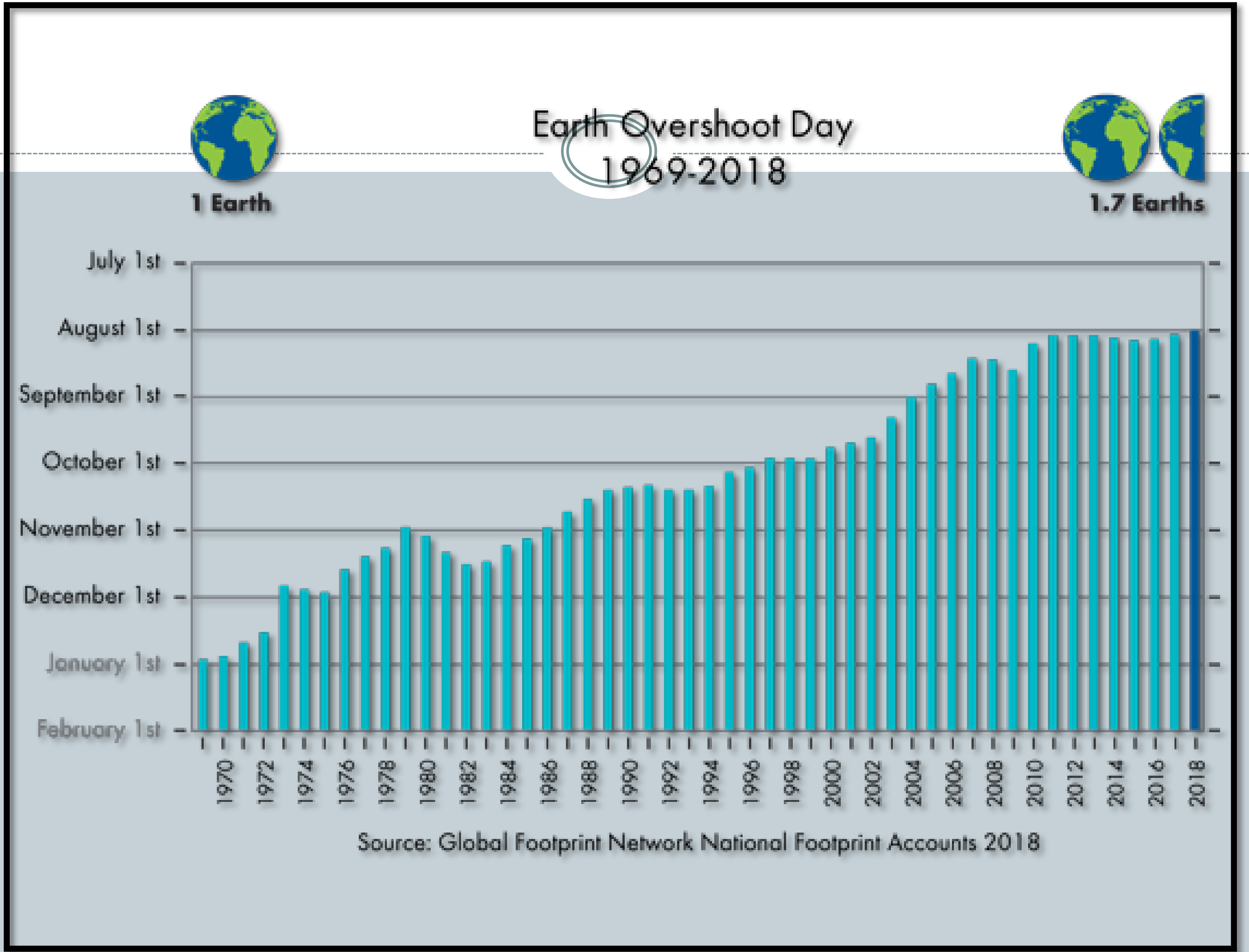
PLANET EQUIVALENT

- It is the ratio of an individual's (or country's per capita) Footprint to the per capita biological capacity available on Earth (1.6 gha in 2019).
- In 2019, the world average Ecological Footprint of 2.7 gha equals 1.75 planet equivalents.


3.0
2.5
2.0
1.5
1.0
0.5
0.0
1960-2008
Ecological Footprint
2008-2050, Scenarios
Moderate business-as-usual
Rapid reduction
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
y-axis: number of planet earths, x-axis: years

EARTH OVERSHOOT

- **Earth Overshoot Day (EOD)**, previously known as **Ecological Debt Day (EDD)**, is the calculated illustrative calendar date on which humanity's resource consumption for the year exceeds Earth's capacity to regenerate those resources that year.
- [World bio-capacity/ World ecological footprint]*365 = Earth Overshoot Day.

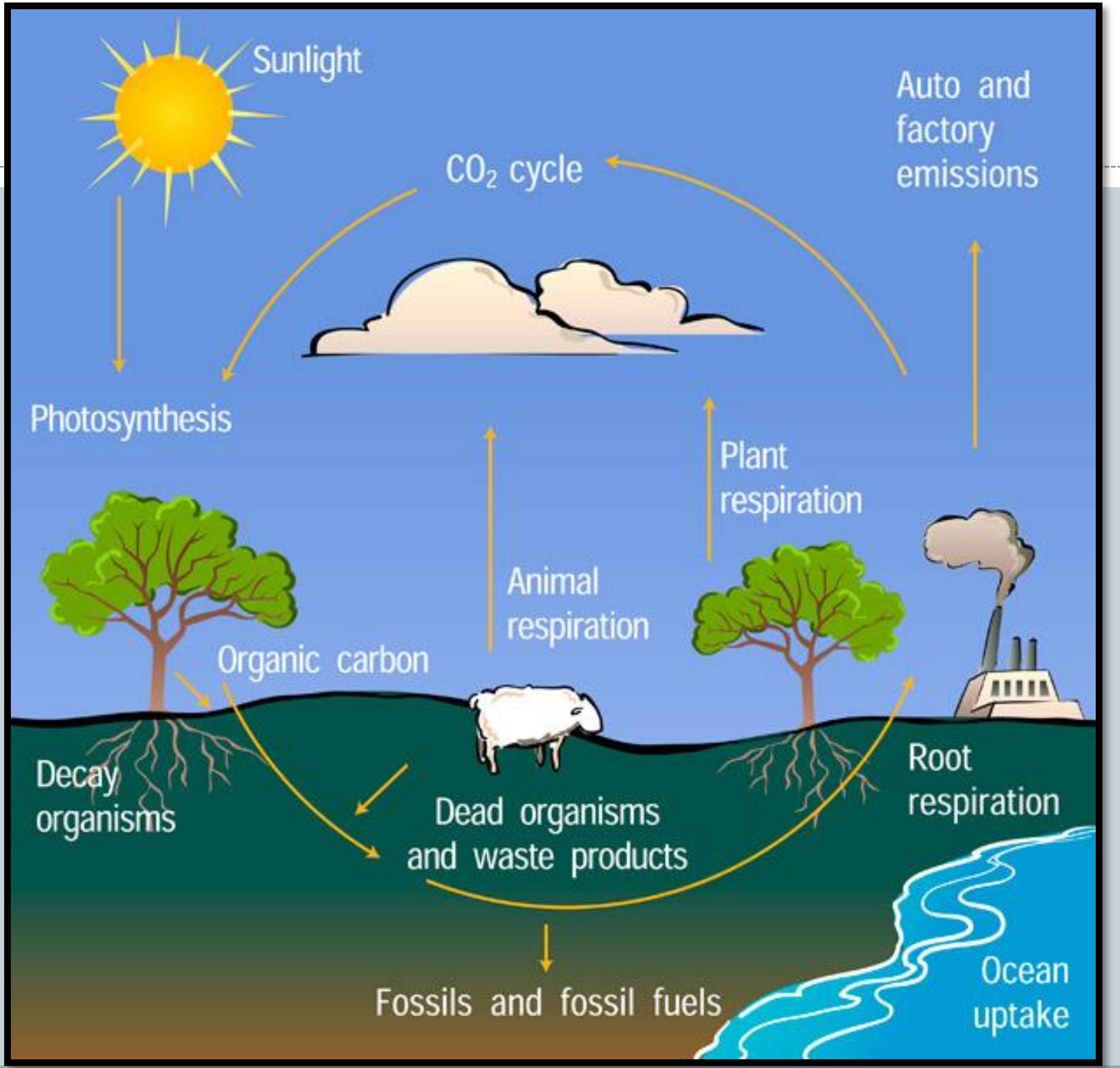


Earth Overshoot Day
1969-2018
1 Earth
1.7 Earths
July 1st
August 1st
September 1st
October 1st
November 1st
December 1st
January 1st
February 1st
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Source: Global Footprint Network National Footprint Accounts 2018

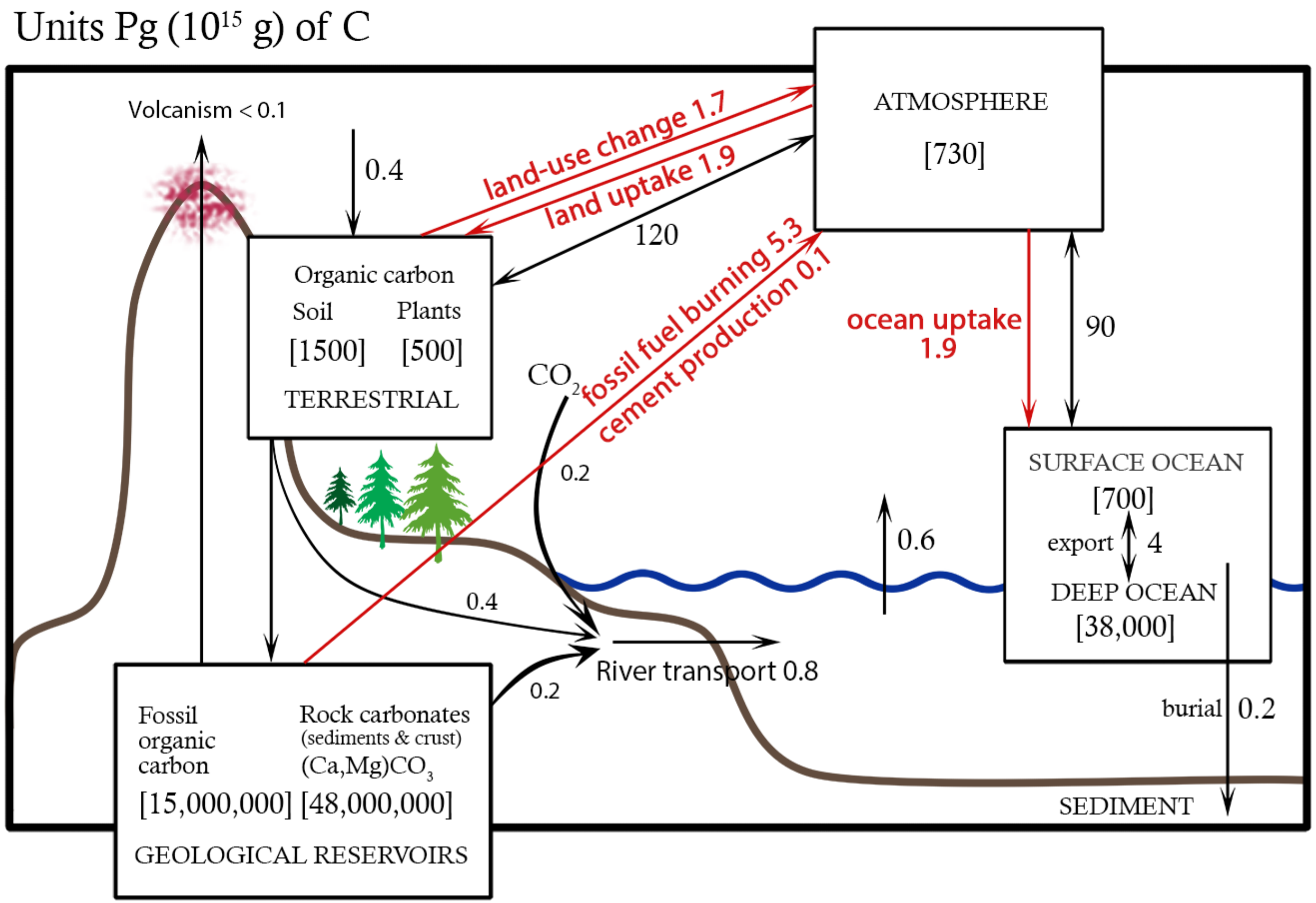
CARBON CYCLE

- The main flows of nature are carbon and oxygen.
- Oxygen is necessary for breathing and carbon is most important part of molecules.
- This flow of carbon in the nature is termed as “Carbon Cycle”.

- Carbon is a major carrier of energy.
- Animals consume food produced by photosynthesis; thus releasing the stored up energy & CO_2.
- The carbon cycle is out of balance and as concentration of CO_2 increases the earth is under going global warming &climatic changes.


Sunlight
Auto and factory emissions
CO_2 cycle
Photosynthesis
Plant respiration
Animal respiration
Organic carbon
Root respiration
Decay organisms
Dead organisms and waste products
Fossils and fossil fuels
Ocean uptake

Human perturbation of carbon cycle



Operational Energy: Thermal Conductivity Models,Operational Energy: Estimation Of Thermal Conductivity.

Operational Energy

- Thermal conductivity (U-value) is the important material property for mechanically conditioned building
- In un-conditioned building thermal capacity is also important because of time lag and amplitude decrement, especially in hot and dry climate
- Long wave emissivity/absorptivity of surface also important

Thermal Properties

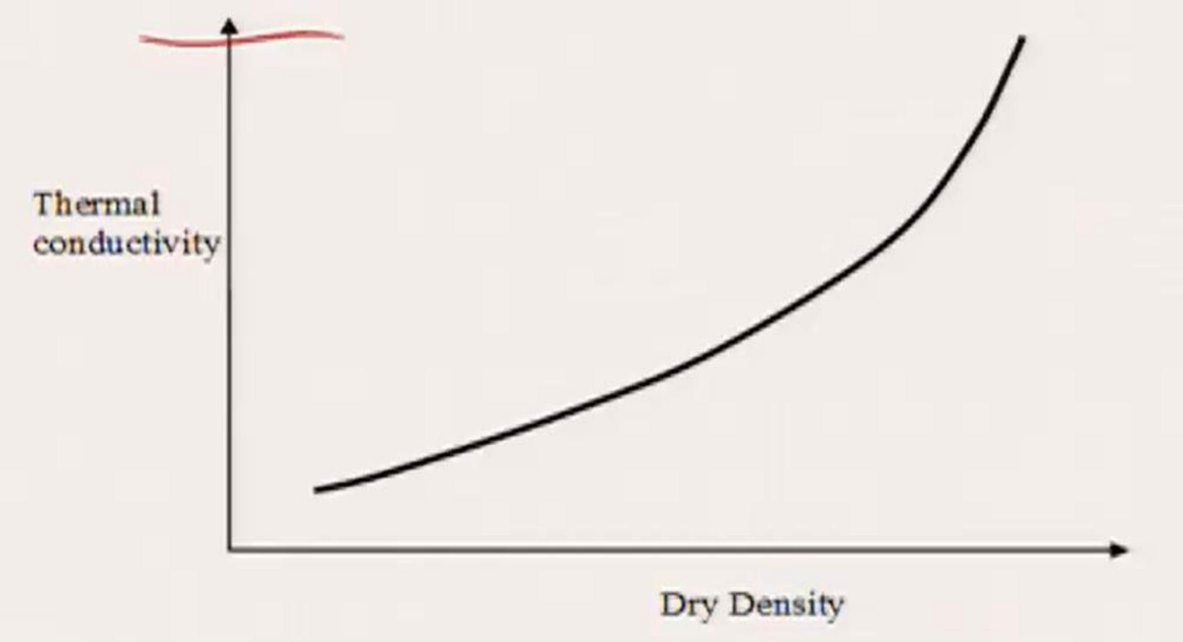
Factors governing thermal properties of porous building are:-

- properties of solid
- porosity and arrangement of pores with respect to solid
- moisture content

conductivity of air at normal temperature is k air is something like 0.025 watt/meter

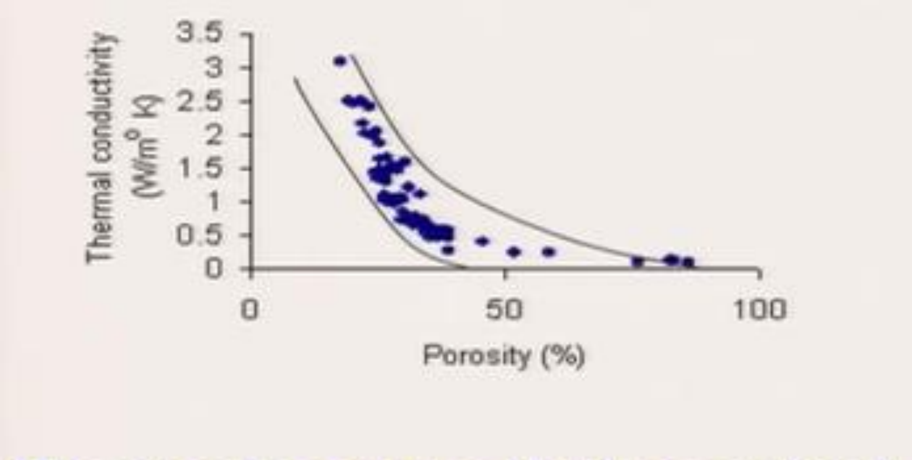
Mechanisms are:

- conduction through solid
- conduction,convection,radiation & evaporation condensation in pores
- thus equivalent conductivity
- Early work thermal conductivity was related to density

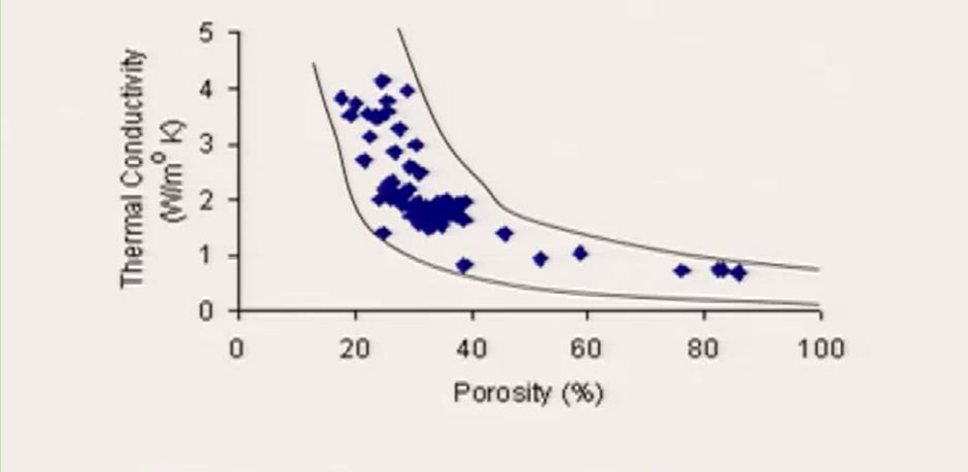


Nature Of Varition:
(measured using hot wire method)

- If porosity increases,thermal condutivity reduces
- where you create pores deliberately by adding foaming agent



Thermal conductivity against Porosity for dry construction material



Thermal conductivity against Porosity for saturated construction material

Early work thermal condutivity was related moisture content through multiplying factors

Jakob's multifying Factors

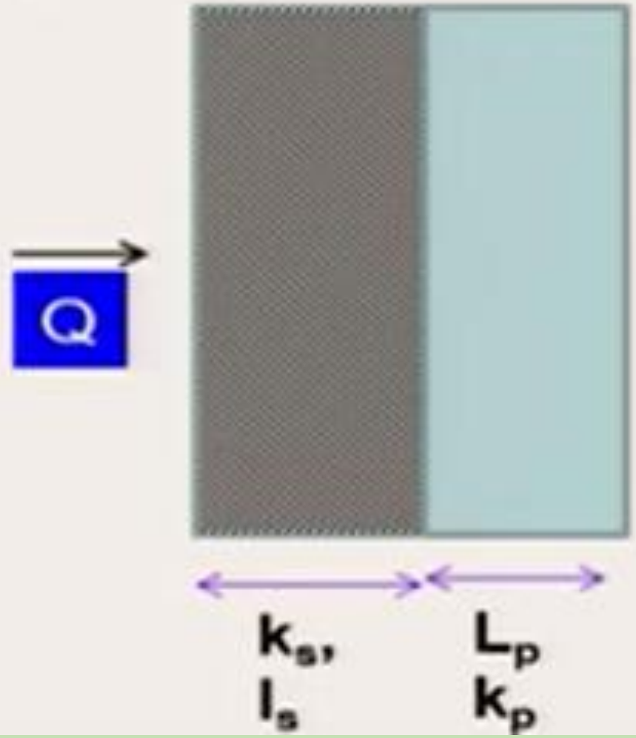
Moisture Content by volume%	1	2.5	5	10	15	20	25
Factor f	1.30	1.55	1.75	2.10	2.35	2.55	2.77

Ohm's law models (series)

$$\frac{(l_p + l_s)}{k_e} = \frac{l_p}{k_p} + \frac{l_s}{k_s}; \quad \frac{1}{k_e} = \frac{1}{k_p} \times \frac{l_p}{(l_p + l_s)} + \frac{1}{k_s} \times \frac{l_s}{(l_p + l_s)} = \frac{p}{k_p} + \frac{(1-p)}{k_s}$$

$$= \frac{1}{k_e}$$

$$k_e = \frac{k_s k_p}{(1-p)k_p + pk_s}$$



For $k_p << k_s$,

$$\frac{k_p}{}$$

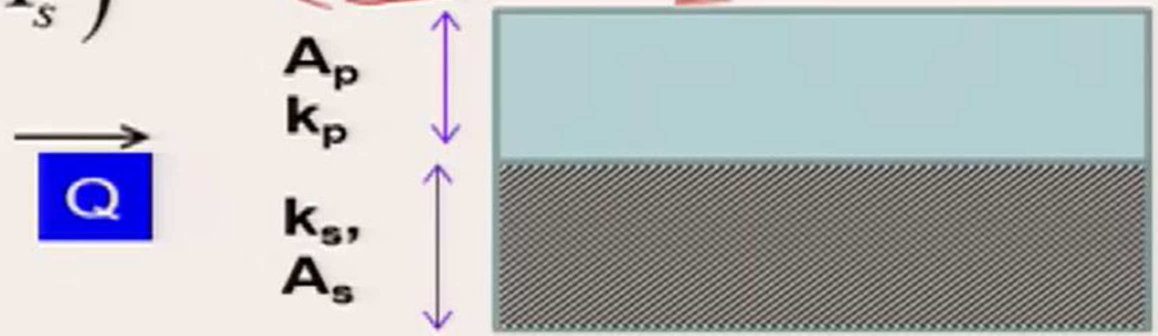
Ohm's law models (parallel)

- Parallel model yields much higher values of Ke than series model

$$(A_p + A_s)k_e = A_p k_p + A_s k_s$$

$$k_e = \frac{A_p}{(A_p + A_s)}k_p + \frac{A_s}{(A_p + A_s)}k_s = pk_p + (1-p)k_s$$

For $k_p << k_s$,



$$k_e = (1-p)k_s$$

Effective medium approximation(maxwell's model)

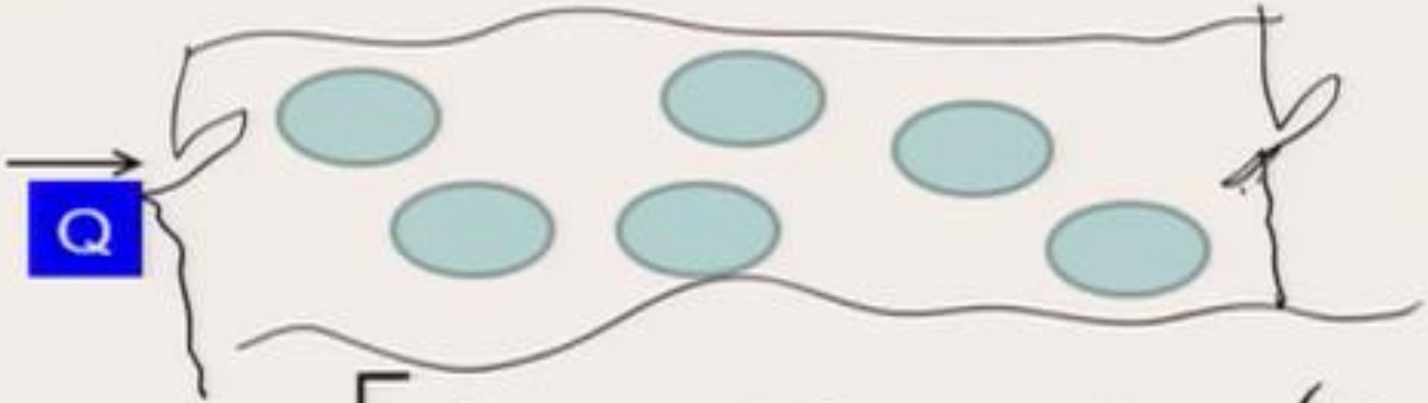
$$k_e = k_c \left[\frac{k_d + 2k_c - 2(1-p)(k_c - k_d)}{k_d + 2k_c + 2(1-p)(k_c - k_d)} \right]$$

Subscript c and d refers to continuous and dispersed phases respectively

Hence one can consider pores dispersed in solid or vice-versa

Solid dispersed in pores

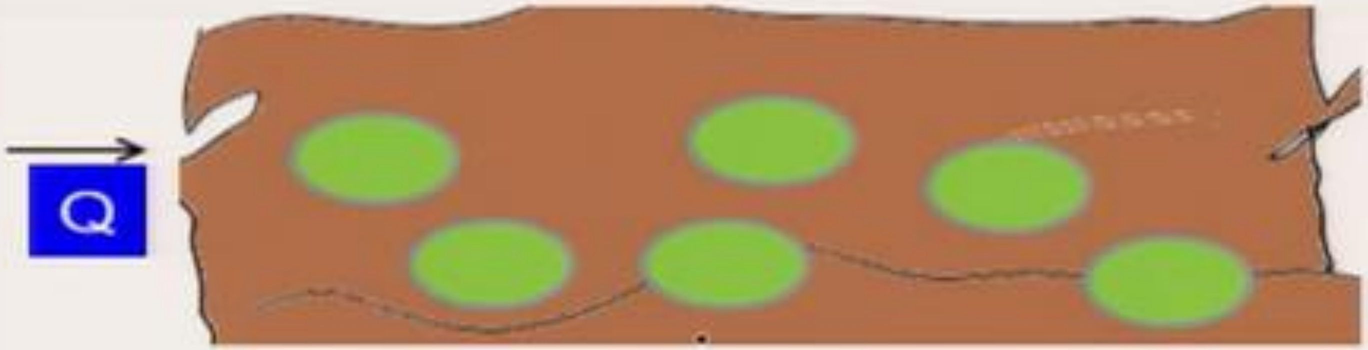
solid dispersed in pores



$$k_e = k_p \left[\frac{k_s + 2k_p - 2p\left(k_p - k_s\right)}{k_s + 2k_p + 2p\left(k_p - k_s\right)} \right]$$

Pores dispersed in solid

Pores dispersed in solid



$$k_e = k_s \left[\frac{k_p + 2k_s - 2(1-p)\left(k_s - k_p\right)}{k_p + 2k_s + 2(1-p)\left(k_s - k_p\right)} \right]$$

EMA model

One can get upper and lower bounds of thermal conductivity from these two models again

For $k_p << k_s$,

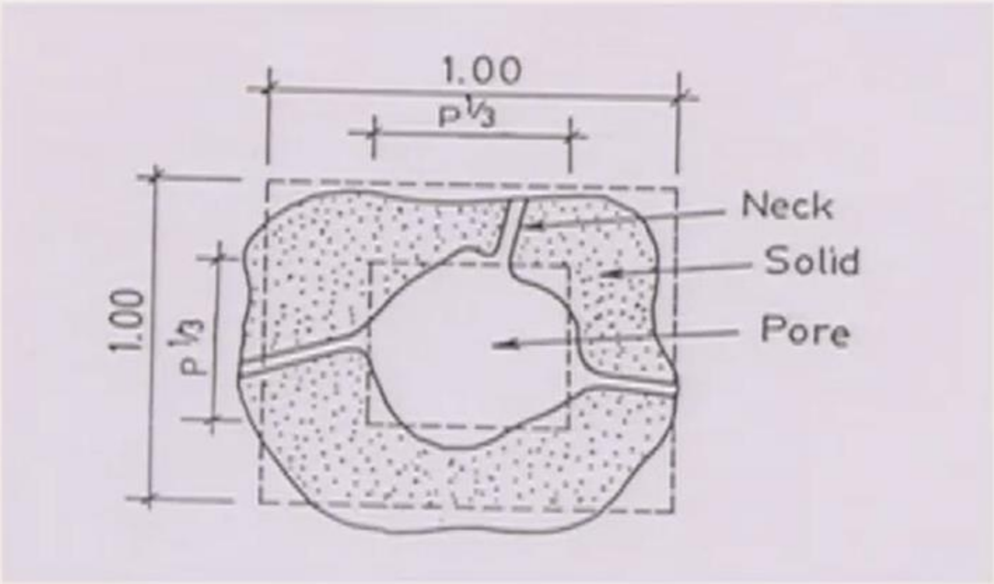
$$k_e = k_p \left[\frac{k_s + 2p(k_s)}{k_s - 2p(k_s)} \right] = k_p \frac{1+2p}{1-2p}$$

And,

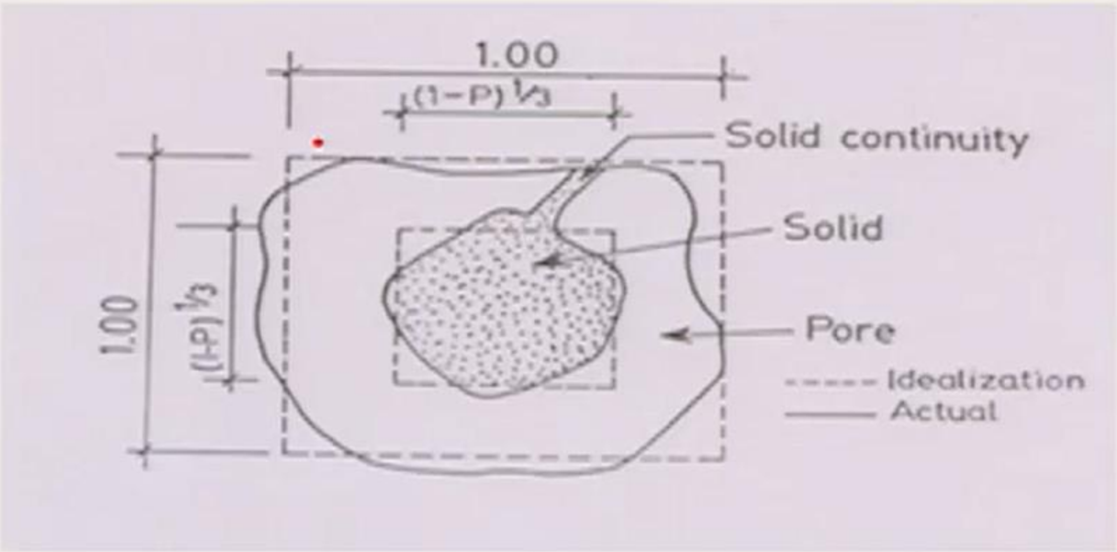
$$k_e = k_s \left[\frac{2k_s - 2(1-p)(k_s)}{2k_s + 2(1-p)(k_s)} \right] = \frac{p}{2-p} k_s$$

3D Model

- PCM (phase change material) they would melt at high temperature absorb heat
- Unit cells (cubical) containing two types of pores are idealized



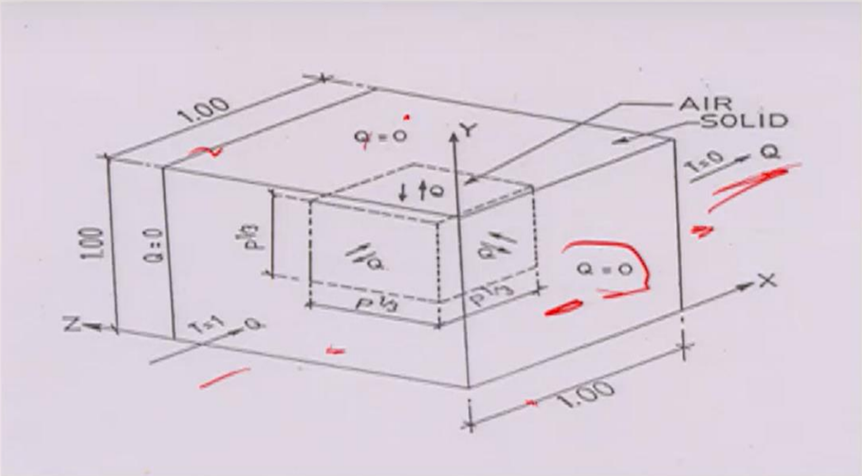
Idealization of unit cells – enclosing pores



Idealization of unit cells – enclosed pores

3D Model

- Heat transfer through this cell for constan temperature (steady state) at two facinf boundary is considered
- The heat flow at four other surfaces assumed to be zero to ensure idealized overall 1D heat transfer with internal 3D heat transfer within cell in solid & pore



λ represent Conductivity of unit cell

The boundary condition and heat flow direction (enclosed pore)

- Steady heat diffusion equation is solved using FEM for two condition, i.e; fully dry and complete saturation.
- Equvalent conductivities are obtained for both types of cells in above two condition as heat flow for unit temperature gradient along direction of flow.
- 4 conductivities of unit cells are obtained.

λ represent equivalent conductivity of unit cell, subscript 1d and 2d represent unit cells of enclosing & enclosed pores respectively. Subscript 1s and 2s for saturated condition

λ_{1d}, λ_{2d}, λ_{1s} and λ_{2s} values were computed using the model for different assumed values of k_s. Empirical equations are obtained relating relevant parameters

Model

- so,here how the A,B,C,D are function of porosity is this A1,B1,B2,A2,C1,D1

The empirical equations are:

$$\frac{1}{\lambda_{1d}} = A1.k_s + B1 \qquad \lambda_{2d} = B2 - A2.k_s$$

$$\frac{1}{\lambda_{1s}} = C1.k_s + D1$$

$$\log_{10}(\lambda_{2s}) = C2 - D2.k_s + E2.\,k_s^{\,2}$$

A, B, C and D are:

$$A1 = 30.99p^2 - 0.46p + 2.29$$

$$B1 = 1.17p^2 - 0.51p + 1.15$$

$$A2 = (0.63p^2 + 3.3p + 0.30) \times 10^{-3}$$

$$B2 = 0.33p^2 - 1.32p + 1.01$$

$$C1 = 1.38p^2 - 0.11p + 0.11$$

$$D1 = 1.52p^2 + 0.98p + 0.82$$

Model

- For random distribution of the type of pores law of mixture is applied

- Equation combining the conductivities of the two cells are combined to get overall effective thermal of the material

- In both dry and saturated states the model is validated with available experimental data

A, B, C and D are:

$$C2 = 0.37p^2 - 0.27p + 0.03$$

$$D2 = 0.30p^2 + 0.04p + 0.02$$

$$E2 = 0.63p^2 - 0.02p + 0.006$$

With known p and k_s constants can be obtained and λ_1 , λ_2 can be calculated

λRepresent Conductivity of unit cell
f represents fraction of enclosed pores

$$\frac{k_{ed}}{k_s} = \lambda_{1d}^{(1-f)} \times \lambda_{2d}^{f} \qquad \frac{k_{es}}{k_s} = \lambda_{1s}^{(1-f)} \times \lambda_{2s}^{f}$$

Thus k_{ed} and k_{es} can be determined when f is also known

Estimation of K

Material	solid cond. (W/m °K)	fraction of enclosed pores	Range of Bulk Density (kg/m^3)	Range of porosity (%)
Quartzite –badar aggregate	4.83	0.792	1751-2114	17.7-30.4
Basalt_badar	3.98	0.84	2310	14.93
Basalt_Jabal	3.85	0.81	2270	16.63
LS2 Badar	3.33	0.87	2270	15.58
LS2 Jabal	3.22	0.79	2300	17.01
SS2 Badar	4.27	0.82	2220	16.59
SS2 Jabal	3.61	0.84	2260	19.27
Quartzite2–badar	4.83	0.87	2260	16.5
Quartzite2 – Jabal	4.28	0.85	2250	18.52
Mortar badar	3.51	0.88	1940	22.99
Mortar Jabal	2.52	0.87	2010	24.10

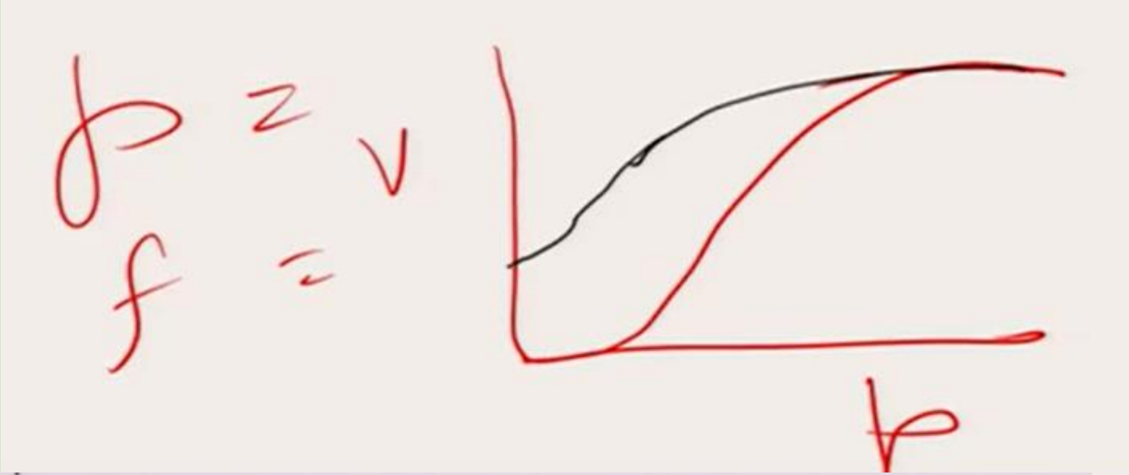
Estimation of k

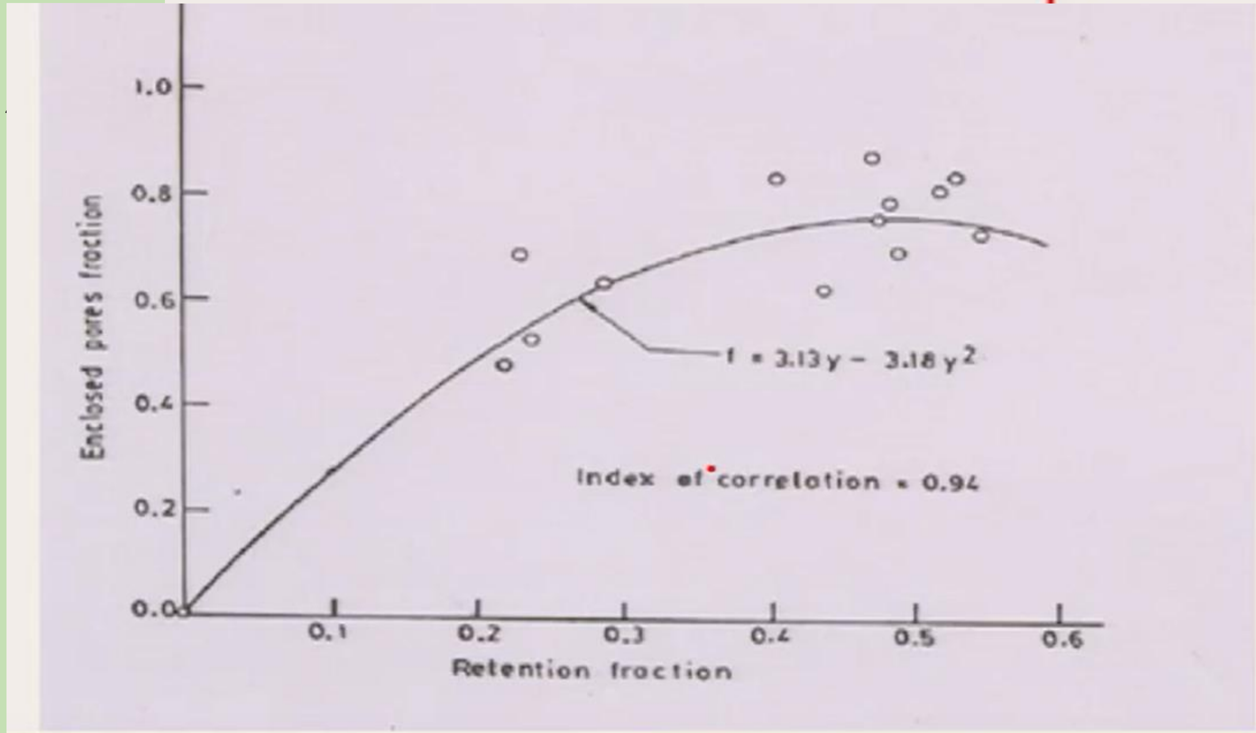
Material	solid cond. (W/m °K)	fraction of enclosed pores	Range of Bulk Density (kg/m^3)	Range of porosity (%)
Fire Bricks	2.72	0.792	1832-2043	24.9-33.3
Clay Brick	2.56	0.567	1423-1863	29.7-45.7
Aerated Concrete	1.10	0.642	345-815	38.7-85.9
Fly ash bricks	0.96	0.835	1000	52

- Example: clay brick with porosity 30% ; find dry and saturated conductivity

Fraction of enclosed pores against ratention fraction

- As your pressure increases volume of intrusion increases
- when you release it doesn't follow the same path
- some of the mercury is entrapped, this entrapped mercury is a measure of the pores which are enclosed by solid
- relationship of this is called retention fraction in mercury intrusion porosimetry





Alternative fuel for cement and embodied energy.

Alternative Fuel for Cement.

Introduction.
Overview of A.F.
A.F. for cement industry.
Benefits of using A.F. in cement production.
Challenge of using A.F. in cement production.
Main A.F. used in the cement industry.
Conclusions.

INTRODUCTION.

- Fossil furls such as coal, petroleum and natural gas most of the energy needs of the world today.
- Coal and natural gas are used in their natural forms, but petroleum and other fossil fuels such as shale and bituminous sands require distillation and refinement to give usable fuel.

- The finite nature of global fossil fuel resources,high prices and most importantly, their damaging effect on the environment underscore the need to develop alternative fuels can extend fossil fuel supplies and help resolve air pollution problem associated with the use of conventional fuels.

- The cement manufacturing industry is also under increasing pressure to reduce emissions.
- Cement manufacturing releases a lot of emissions such as carbon dioxide and nitro-oxide.

- IT is estimated that 5% of global CO_2 emissions originated from cement production.
- The use of A.F. in cement manufacturing, therefore do not only afford considerable energy cost reduction, but they also have significant ecological benefits of conserving non-renewable resources, the reduction of waste disposal requirement and reduction in emissions.

Overview of alternative fuels.

- Alternative fuels and alternative sources of energy usually fall under eight broad headings: biofuels; natural gas; waste-derived fuels; wind energy; hydroelectric power; solar energy; hydrogen; and nuclear energy. Alternative fuels discussed in this chapter are predominantly agricultural biomass, non-agricultural biomass (e.g. animal waste and by-products), chemical and hazardous waste, and petroleum-based fuels.

- Solid biofuels (generally called biomass) include plant tissues such as wood, charcoal and yarns; farm wastes such as coffee husks, straw, sugarcane leaves, sugarcane biogases, rapeseed stems, palm nut shells, rice husks, etc.; and non-agricultural biomass such as animal fat, dung, meats and bones; and household or industrial biological degradable wastes. These materials are primarily composed of carbon-based organic matter, which releases energy when it reacts or combusts with oxygen.

- Solid biofuels should be distinguished from solid fossil fuels which are of biological origin but which are non-renewable. Similarly, liquid biofuels should be distinguished from fossil liquid fuels which are also of biological origin but which are non-renewable.
- Liquid biofuels are transport fuels, primarily biodiesel and ethanol. Another form of biofuel is biogas. Biogas is the product of organic material decomposition, composed mainly of methane and carbon dioxide.

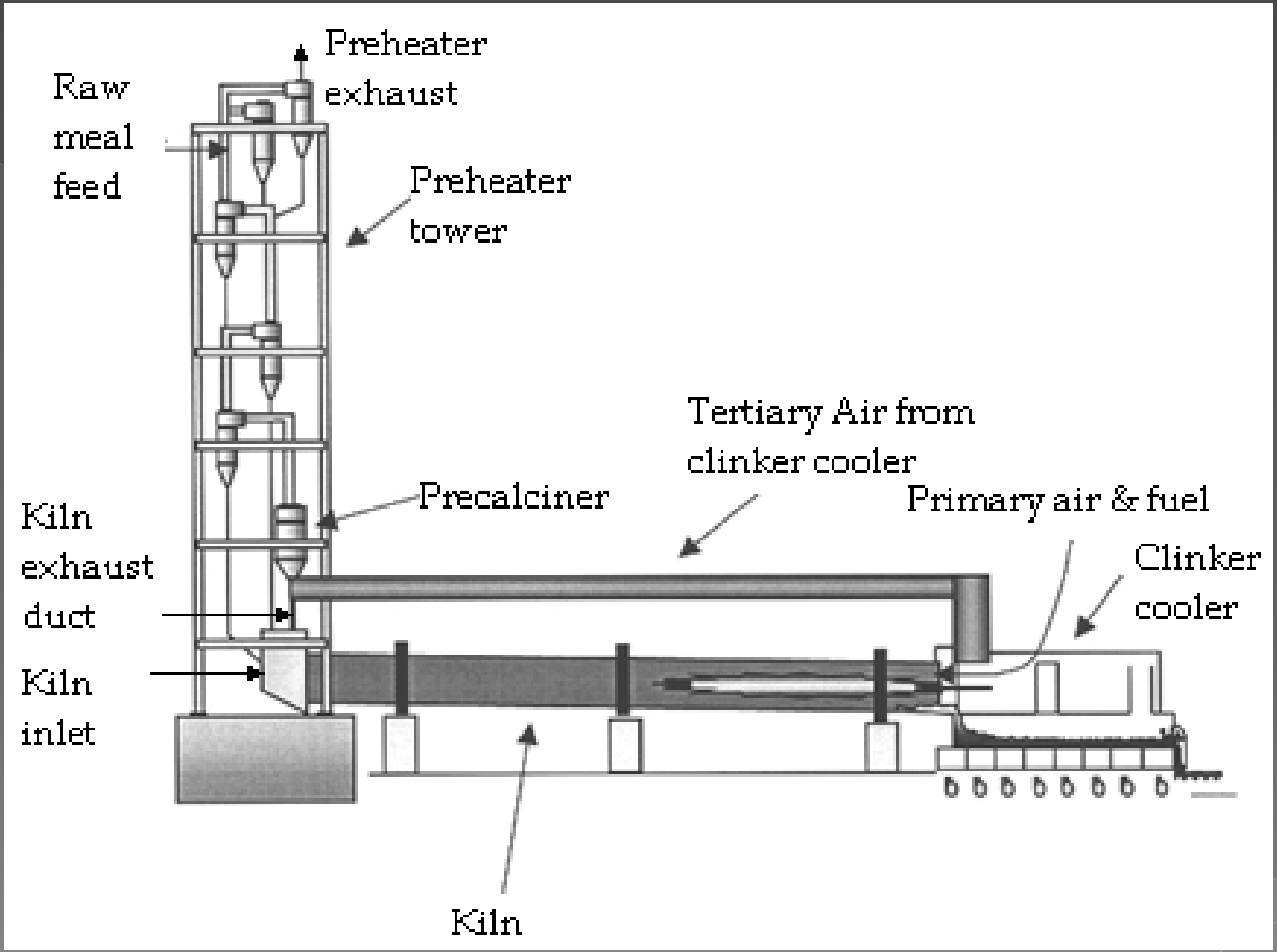
A.F. options for the cement industry.

- Coal is the primary fuel burned in cement kilns, however, the use alternative fuels in cement kilns is now common and increasing. The range of alternative fuels is extremely wide.

Benefits of using A.F. in cement production

- Cement producers worldwide are striving to lower their production costs. One effective method of achieving this end is the use of alternative fuels. Use of low-grade alternative fuels such as waste coal, tyres, sewage sludge, and biomass fuels (such as wood products, agricultural wastes, etc.) in precalciners is a viable option because combustion in a precalciner vessel takes place at a lower temperature. In precalciners where kiln exhaust gases pass through, the NO_x emissions are much reduced due to reburn reactions.

- There is an increased net global reduction in CO_2 emissions when waste is combusted in the cement kiln systems as opposed to dedicated incinerators, resulting in reduction in the CO_2 penalties. Since alternative fuels are often deemed cheaper than conventional fossil fuels, the possibility of a competitive edge is generated.


Preheater exhaust
Raw meal feed
Preheater tower
Tertiary Air from clinker cooler
Precalciner
Primary air & fuel
Kiln exhaust duct
Clinker cooler
Kiln inlet
Kiln

- The process of clinker production in kiln systems creates favorable conditions for use of alternative fuels. These include: high temperatures, long residence times, an oxidizing atmosphere, alkaline environment, ash retention in clinker, and high thermal inertia. These conditions ensure that the fuel’s organic part is destroyed and the inorganic part, including heavy metals is trapped and combined in the product.

- The wastes used as alternative fuels in cement kilns would alternatively either have been land filled or destroyed in dedicated incinerators with additional emissions as a consequence.

Challenges of using A.F. in cement production

- Alternative fuels used in cement manufacturing have different characteristics compared to the conventional fuels. Switching from conventional fuels to alternatives fuels presents several challenges that must be addressed in order to achieve successful application. Poor heat distribution, unstable precalciner operation, blockages in the preheater cyclones, build-ups in the kiln riser ducts, higher SO_2, NO_x, and CO emissions, and dusty kilns are some of the major challenges.

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- The operation of cement kiln system is not only affected by the chemical composition of the main components of the raw meal but also the combustion and consequently the fuel used.
- The use of a type of fuel is therefore subject to the constraints imposed by any deleterious effect on cement quality, refractory life, gas and material flow or potential emissions to the atmosphere.

- In most kiln systems the fuel ash is incorporated into the clinker thereby changing the compound composition of the product.
- The main constituents of fuel ash are silica and alumina compounds which combine with the raw materials to become part of the clinker.

- The composition of fuel ash tend to limit the level of replacement of more conventional fuels, for instance rice husks have been used to replace 5 – 7 percent of traditional fuels since the ash contains 78 – 90 percent silica. Fuel ash with high content silica can on the other hand provide a very satisfactory means of increasing the silica modulus of the clinker, thus making it possible to reduce the amount of ground sand incorporated into the feedstock.

- Approximately 95 percent of clinker consists of oxides of CaO, SiO_2, Al_2O_3, and Fe_2O_3 and the remainder consists of the so-called minor constituents.
- In cement manufacturing care is taken to avoid constituents which, even when present in small amounts (< 1percent), may have adverse effect upon the performance of the product and/or the production process.

- The alkali metals Na_2O and K_2O have a very strong affinity for SO_3 and where there is sufficient sulphate present in the clinker, the alkalis are normally present as compounds of sulphates such as K_2SO_4, Na_2SO_4, aphthilalite $Na_2SO_4 \cdot K_2SO_4$ and langbeinite $2CaSO_4 \cdot K_2SO_4$ (Hewlett, 2004; Newman, et al., 2003).
- The effect of other trace elements such as fluorine, barium, chromium, lead, manganese, thallium, titanium, vanadium and zinc on quality of cement range from very small to negligible.

- Some of the waste materials used as alternative fuels in cement kiln systems such as polyvinylchloride (PVC), chlorinated hydrocarbons, sewage sludge, and meat and bone meal can increase the amount of chlorine (Cl) introduced into the system (Saint-Jean et al, 2005). Fuels containing high (> 0.7 percent Cl) can adversely affect the performance of some types of electrostatic precipitators on wet process kilns.

- The incomplete combustion, poor heat distribution and unstable precalciner operation are problems associated with switching from conventional fuel to alternative fuels (Roy, 2002). The arrangement of combustion in such a manner as to create a reducing condition in some zones of the precalciner is useful for the diminution of NO_x emissions.

Main A.F. used in the cement industry

- Well-established technology, on the one hand, allows the rotary kiln of any cement plant to be fired with low-volatile fuels such as petcoke, low-volatile bituminous coal, and anthracite, without problem (Nielsen et al., 1986). On the other hand, high volatile-low calorific value alternative fuels have limited use in the kiln primary firing system due to their relatively low combustion temperatures.

- The use of low-volatile fuels in precalciners, often requires design and operational modifications of the precalciner, or specially designed precalciners .
- Petcoke.
- Sewage sludge.
- Used tyres.
- Meat and bone meal.
- Agricultural biomass.

Conclusions

- This presentation presents the current fuel alternatives to fuel of fossil origin for cement manufacturing. The presentation introduces different potential alternative fuels that can be used in the cement manufacturing industry and how these fuels are to be considered in order to avoid negative effects on the final product. The type of fuel used in cement production is subject to the constraints imposed by any deleterious effect on cement quality, refractory life and emissions released to the atmosphere

- The benefits of using alternative fuels are highlighted, showing that good planning is needed before the alternative fuel to be used is chosen. The presentation has included detailed study of the main alternative fuels used in the cement industry including petcoke, sewage sludge, used tyres, meat and bone meal, and agricultural biomass.

FUEL FOR CEMENT

CEMENTITIOUS AND SUPPLEMENTARY CEMENTITIOUS MATERIALS

FUEL FOR CEMENTS

- PRIMARY FUEL : COAL
- OTHER FUELS SUCH AS :
- GAS
- OIL
- LIQUID WASTE MATERIALS
- SOLID WASTE MATERIALS
- PETOLEUM COKE

ALTERNATIVE FUELS

- CO - PROCESSING
- USE OF ALTERNATIVE IN COMBUSTION AND PRODUCTION PROCESS
- SUBSTITUTING PRIMARY FUELS WITH WASTE
- CONSISTS OF COMBUSTIBLE MUNICIPLE WASTE
- REFUSE DERIVED FUELS (RDF)

ALTERNATIVE FUEL BENIFITS

- REDUCE FOSSIL FUEL CONSUMPTION
- LOWER ENERGY COST
- FAST RETURN ON INVESTMENT
- CONTRIBUTE TO LOCAL WASTE MANAGEMENT

CEMENTITIOUS MATERIALS

- COMPRISE THE GLUE THAT HOLDS CONCRETE TOGETHER
- INCLUDE TRADITIONAL PORTLAND CEMENT
- OTHER CEMENTITIOUS MATERIALS
- FLY ASH
- GROUND GRANULATED BLASTFURNACE SLAG (GGBS)
- LIMESTONE FINES
- SILICA FUMES

SUPPLYMENTRY CEMENTING MATERIALS (SCMs)

- HARDENED CONCRETE THROUGH HYDRAULIC OR POZZOLANIC ACTIVITY
- FLY ASH :

  - BY PRODUCT OF COAL FIRED FURNACES AT POWER GENERATION FACALITIES

  - NON COMBUSTIBLE PARTICULATES

  - REMOVED FROM THE FLUE GASES
- GGBFs :

  - NON – METALLIC MANUFACTURED BYPRODUCT FROM BLAST FURNACE

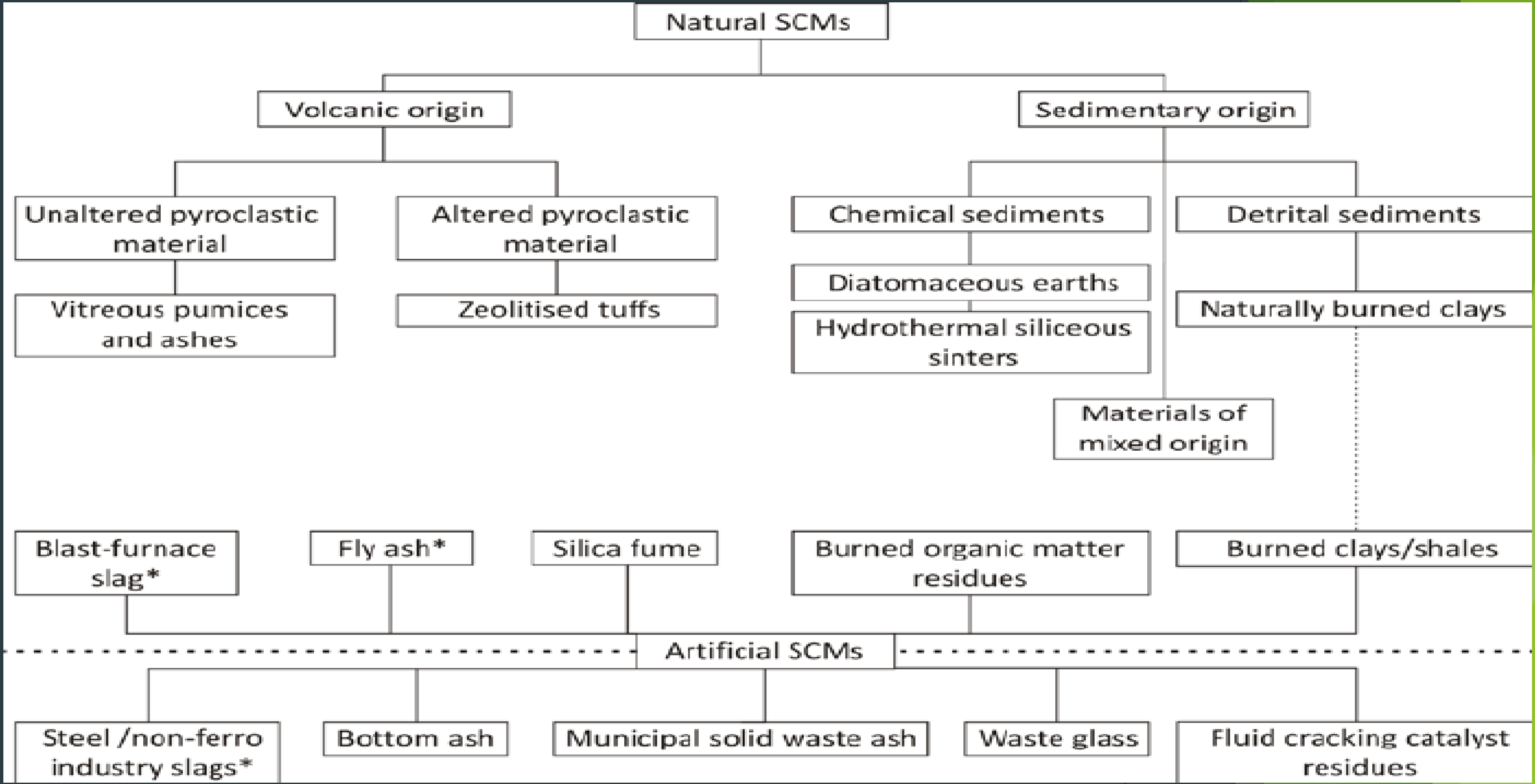
  - LIQUID SLAG IS REPEATEDLY COOLED TO FORM GRANULES
- SILICA FUME

  - HIGHLY REACTIVE POZZOLANIC MATERIAL

  - 100 TIMES SMALLER THAN AVERAGE CEMENT GRAIN

WHY SCMs ?

- IMPOVED CONCRETE PERFORMANCE IN ITS FRESH AND HARDENED STATE
- IMPROVED WORKABILITY, DURABILITY AND STRENGTH
- ALLOW THE CONCRETE PRODUCER TO DESIGN AND MODIFY
- DESIRED MODIFIATION
- SUSCEPTIBLE TO CRACKING ANDINCREAD HEAT GENERATION


Natural SCMs
Volcanic origin
Sedimentary origin
Unaltered pyroclastic material
Altered pyroclastic material
Chemical sediments
Detrital sediments
Vitreous pumices and ashes
Zeolitised tuffs
Diatomaceous earths
Hydrothermal siliceous sinters
Naturally burned clays
Materials of mixed origin
Blast-furnace slag*
Fly ash*
Silica fume
Burned organic matter residues
Burned clays/shales
Artificial SCMs
Steel /non-ferro industry slags*
Bottom ash
Municipal solid waste ash
Waste glass
Fluid cracking catalyst residues

THANK YOU