Trends and development of building materials

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Trends and development of building materials

Evolution des matériaux de construction

Die Entwicklung der Baustoffe

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SUMMARY
This paper gives some fragmentaric aspects on the development of building materials against the background of trends in building industry, raw materials supply, waste products utilization and environmental influences. The aspects mentioned are of major interest today and will be of still increasing interest in the future.

RESUME
Quelques aspects fragmentaires illustrent l'évolution des matériaux de construction par rapport à l'industrie de la construction, aux ressources en matières premières, à l'utilisation des déchets et aux influences de l'environnement. L'importance de ces questions s'accroitra encore à l'avenir.

ZUSAMMENFASSUNG
Es wird über Teilaspekte der Entwicklung von Baustoffen berichtet, welche von der Bauindustrie, den Rohmaterialquellen, der Wiederverwendung von Abfällen sowie der Umwelt beeinflusst werden. Diesen Aspekten kommt grosse Bedeutung zu, und sie werden in Zukunft noch an Bedeutung gewinnen.

The building industry in the industrialized countries is of a size which gives it a significant and direct influence on the entire economy of the society. Its character is to serve essential, human requirements - good housing and working environmental conditions - and political considerations and decisions will therefore strongly influence the conditions and realizing of the building activities.

In many countries the industrial and economical development during the 60:ies caused an extensive increase in the production of dwellings. The large number of equally aged buildings has today formed the base for an increasing market for repair and rebuilding. This is in my opinion an interesting field of development - also from a material point of view - as modified ways of living and new requirements of the consumers will lead to modifications of the existing buildings.

The production of building materials - the building material industry - is representing a large part or approximately half of the total building costs. Some characteristics of this industry is that the character and size of its products is varying over a wide range. The classical materials for construction purposes - steel, concrete, brick and wood - is included but also finishing and furnishing materials such as wall and floor coverings, carpenting and supply system components.

Taking into account the importance of the building materials it is of obvious interest to make attempts to judge the development and conditions of the building material industry. In this paper will therefore be discussed some factors which are reasonable to assume will be of importance to the future development. Stress is put on a discussion of the synthetic, polymeric materials - the plastics - which today are used to a great extent in building.

Furthermore is discussed the development and the possibilities of further development of the existing material categories, specially the mineral-based materials. These do in my opinion represent extraordinary interesting fields of development, specially as far as raw materials supply and energy shortage is concerned. In this connection is briefly mentioned the possibilities of the composite materials. Finally some comments are made on the environmental impact on the building materials. Firstly, however, some essential factors in the general trends of building is discussed.

Building weights

The traditional building in Sweden as well as in other developed countries using concrete, brick and steel as dominating material can be described as a "heavy" way of building. The weights of the buildings were high and the principles and design of foundation constructions were fitted to this way of building.

Increased requirements - for instance concerning heating economy - lead to a development of the building components towards specified function in different respects and the new high-effective insulating materials - e.g. mineral wool - as well as light-weight material saving good bearing structures formed a natural part of this development. One interesting concequence is spotlighted by fig. 1 in which the total weights of the buildings is shown. The values indicate that the wheight per sq.meter dwelling area is reduced by ca 50 % during the period 1925-72. For buildings for industrial purposes this trend is still more pronounced and the concept "leight weight building" is today well established. High utilization of the materials in combination with moderate requirements on service life time has lead to extremely low building weights and to a drastic re-thinking as far as foundation design is concerned. However, it must be stressed that this development has not been without problems and an increased sensitivity to damage - e.g. to fire - for these buildings has lead to requirements from the insurance companies and others for research activities in the relevant fields.

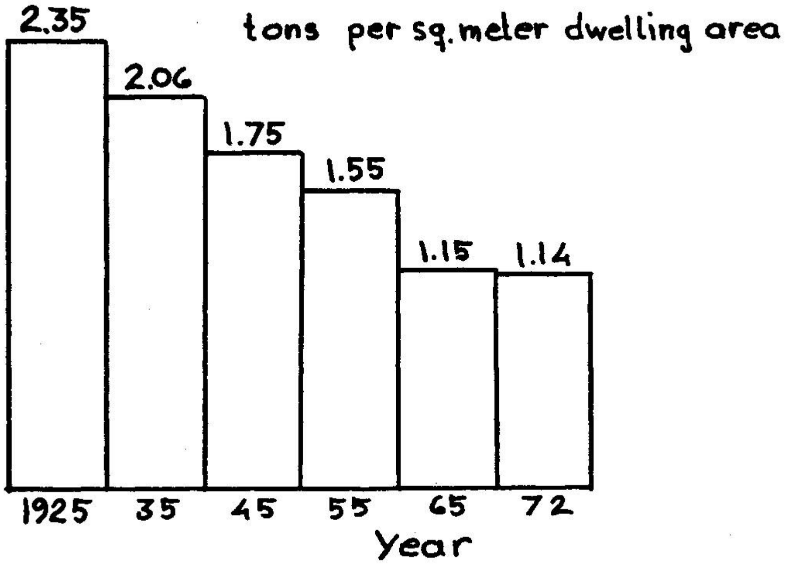


Fig.1 The development of building weights in Sweden during the period 1925 - 1972

It seems to be obvious that a continued development can give us buildings with a level of performance that was beyond reallity in the past probably, however, in combination with a reduction of the service life time. A qualified, scientific analysis of the service life time concept is therefore an unconditional requirement if the possibilities of this building shall be fully utilized.

Today's materials - further development

In general it can be stated that the building industry is creating products of high service life time and intended to satisfy primary, human requirements. It is therefore natural that the tendency to radically new thinking and changes as far as building materials and design are concerned is fairly small. As a consequence the large groups of materials which are today dominating the market (wood, concrete, light-weight concrete, brick, steel) are well known since long ago. These properties have been continously improved up to a level where further, essential developments will need a large i put of time and money , (However, there are probably large and interesting possibilities for the development of new products as well as of processes for production.

In some cases the today's level of material properties is constituted by several requirements some of which are contradictory. One example is the leight weight concrete of different kinds (steam cured or light weight aggregate concrete) where an increase of the strength will be combined with a reduced thermal conductivity. As the material is normally used both for load bearing and heat insulating purposes the two properties must be balanced against each other.

Energy aspects

The development during the last years has emphasised the importance of the energy aspects in building design, construction and maintenance. As far as building materials are concerned two main aspects can be separated. Firstly, materials must be given such properties that they can be used for keeping the energy consumption of the building during its normal service at an acceptable level. Secondly, the energy consumption for the production of the materials must be kept under observation.

Concerning the energy consumption of the building the heating energy forms the dominating part in many countries, e.g. in northern Europe and North America. The heat insulating properties is therefore of primary importance. However, also other properties which directly or indirectly will influence the heat insulating ability of the building components must be taken into account. This can be examplified by moisture properties, strength and deformation properties and by the durability of the materials. It can be mentioned in this connection that the developments of the insulating materials have been brought so far that essential reductions of the heating energy by increasing the insulating capability of the materials are hardly possible. Disturbances occuring from lack of workmanship and similar influences will have far greater effect to the behaviour of the component than a marginal reduction of the conductivity of the material.

The manufacturing process of the materials is in most cases more or less energy consuming. Relatively accurate information is available about this consumption for different materials and some rough figures are listed below.

Steel	27	MJ/kg
Aluminium	113	"
Brick	4	"
Concrete	2,4	"
Wood	0,7	"
Plastics	48	"

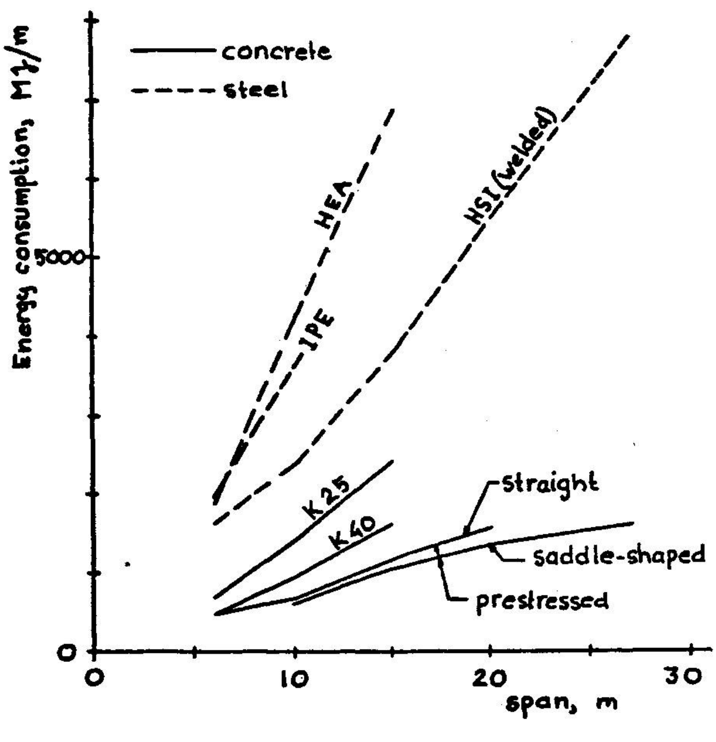


Fig.2

Energy consumption for simply supported beams of concrete and steel.

The problem is to put these figures in relation to the performance of the materials. Many attempts in this direction have been made. One example is given by fig. 2 in which the energy consumption for a simply supported beam is given at different span, load bearing capacity and choice of material /Beijer, 1975/.

Composite materials

The development of so called composites is often the result of the necessity to combine the characteristic properties of different types of materials. Examples of composite materials can be taken from the traditional materials, e.g. concrete, combining stone aggregate with a matrix of cement parte. Depending on the ratio between the mixing components the properties of the concrete - specially the strength - can be varied within fairly wide limits. Some of the main disadvantages of concrete are the high density and the high thermal conductivity. These disadvantages can to some extent be compensated by using other aggregate materials and during the last years many types of light weight aggregates have been used. These materials can consist of e.g. natural porous minerals, expanded clay or flyash from heating plants.

The use of "concrete" with porous aggregate was known already to the ancient Romans. In Italy many vulcanic materials - such as pumice stone or lava - was used as aggregate. Many buildings of this kind are still standing and the Pantheon in Rome (errected in its present form about 120 AD) is probably one of the most famous examples (fig. 3)

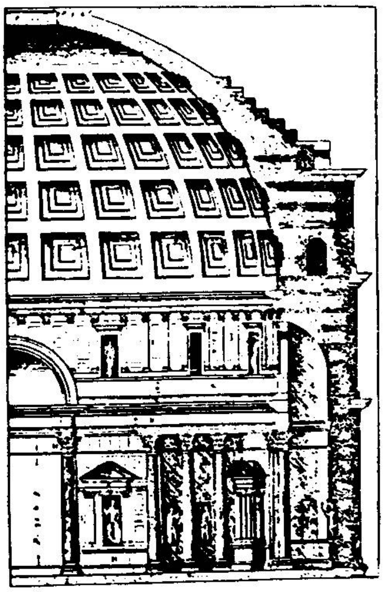


Fig.3

Pantheon in Rome. The dome was errected around 70 AD.

In early 19:ies some waste products from industrial processes were used in England for this purpose. Many coal-fired power plants produced a type of light porous slag clinker which could be used for the manufacturing of heat insulating blocks.

The next step after having used natural materials was to develop industrially produced light weight aggregates. In the US the first furnace for expanded, sintered clay was put into service in 1917 and about ten years later (1928) a corresponding production of granulated slag started. In Europe a production of this type was not started until the 1930:ies.

The porous structure gives the light weight aggregate concrete a reasonably good insulating capability. In many parts of the world however, these materials are also used for load bearing structures. In such cases the aggregate density is normally chosen higher than for insulation purposes. In fig. 4 is shown a relation between compressive strength and gross density for light weight aggregate concrete at varying water-air/cement ratio, aggregate density and the content of non-purpose sand filler /Skarendahl, 1973/.

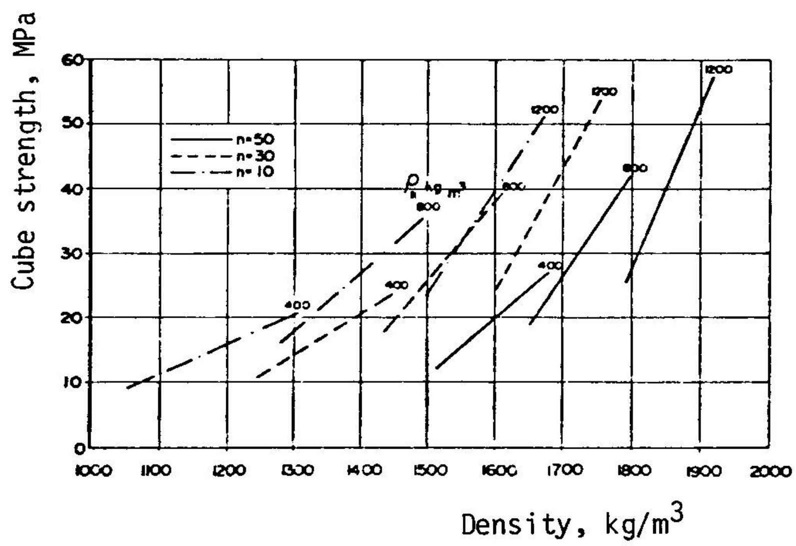


Fig. 4 Relation between strength and density for light weight aggregate concrete.

One further disadvantage of normal concrete as well as light weight concrete is the capillarity and other moisture-related properties. The water content in all hyproscopic materials will significantly influence almost all essential properties, in most cases so that the material deteriorates when the moisture content increases. It has been shown that small additives can change the concrete from a hydrophil to a hydrophob material and drastically improve the properties in this respect /Berge, 1978/.

Normal concrete is characterised by low tensile strength as composed to the compressive strength. In the classical design of concrete structures the tensile strength is therefore neglected. (However, when analysing the shear stresses and deformations of the structure the effect of the tensile strength must be taken into account). The ductility of the material is low and the type of fracture in non-reinforced concrete is normally characterised as brittle. One interesting and promising method to neutralize this disadvantage is represented by the use of fibre reinforced concrete. The influence on the properties of a fibre reinforcement is shown in fig. 5 in which the relation between elongation and tensile stress (in bending) for test beams of non-reinforced and fibre reinforced (2 % by volume) cement mortar is given /Krenchel, 1978/. In fig. 6 is shown load-deflection curves for cement mortar test beams with varying content of steel fibers. It is obvious that even small contents of fibers can essentially improve the material /Lankard, 1972/.

Polymeric materials (plastics)

The polymeric materials are extensively used in modern buildings in many applications e.g. for wall and floor coverings, points and glue and for furnishing. This group of materials is characterized by great flexibility and the properties can be varied within wide limits. These advantages together with manufacturing methods which are well suitable for mass production has added to the building materials market a great number of products with properties quite different from these of the traditional materials. Resistance to moisture and cleaning agents are only some of the advantages which can be achieved with plastic materials.

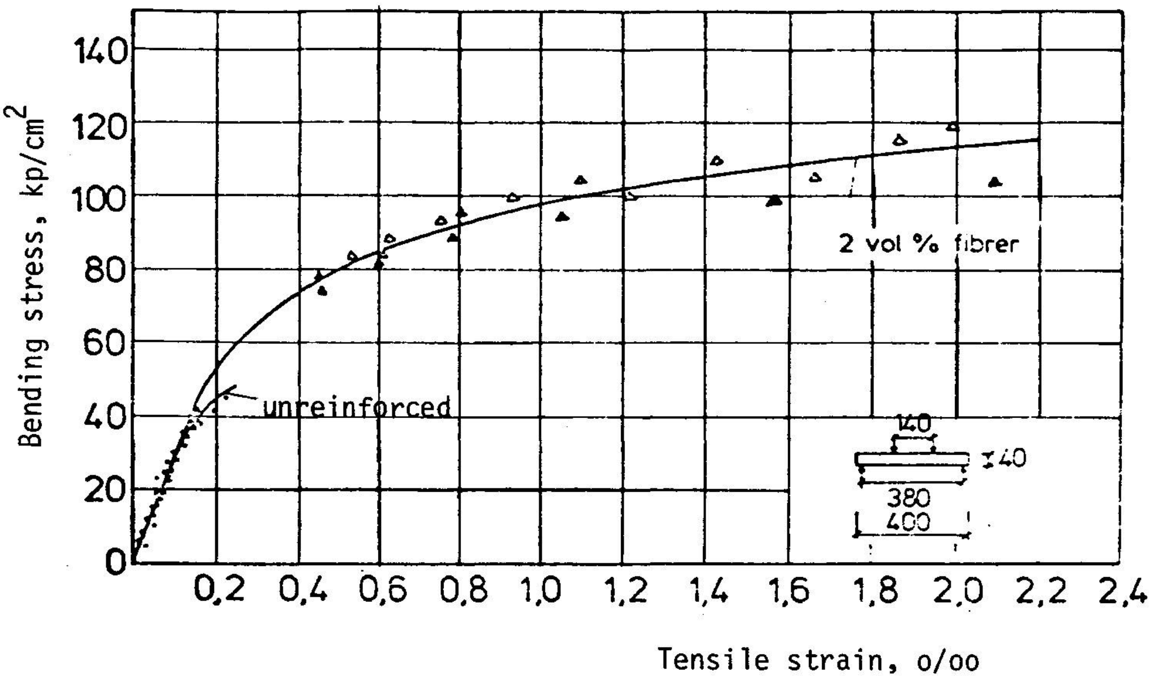


Fig. 5 The tensile stress in bending as a function of the bending strain on the tension side in the case of bending of non-reinforced and steel fibre reinforced mortar beams.

Fig. 5.

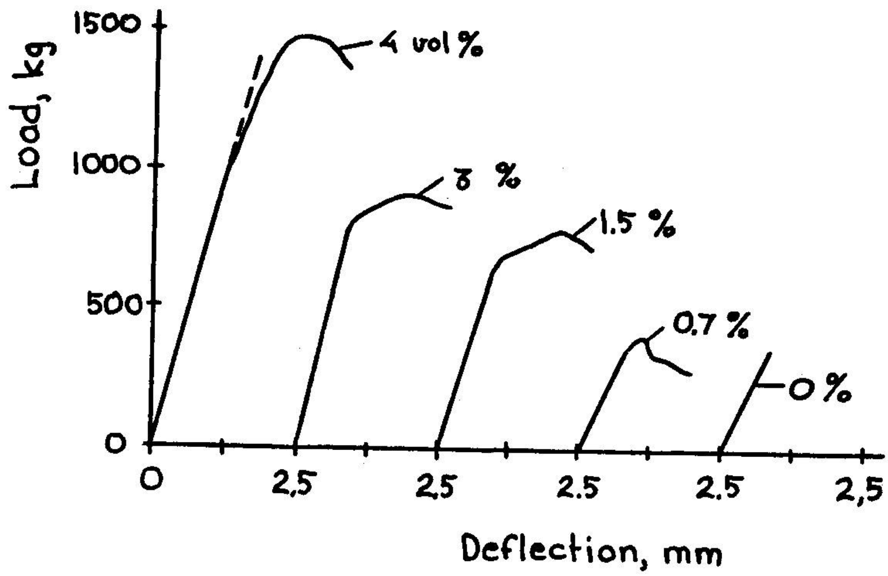


Fig. 6 Load-deflection curves for test beams of cement mortar with steel fibre content of 0 - 4 % (by volume)

In spite of this some factors can be stated which constitutes fairly strict limits for the use of plastics in building and consequently for further expansion. Primarily, three such factors can be separated.

The raw material supply will probably cause problems in the near future. Most plastic processes use petroleum products as raw material and the present situation in this field makes it obvious that the costs will increase and the use for building purposes will be reduced for the benefit of other applications - such as machine and tool industry - were the level of refinement is higher and where consequently the price of the raw material is of minor importance.

The use of plastics in building is relatively young and the rapid - almost explosive - development has taken place during the last two decades. The picture of the materials as far as changes of the properties during the life cycle of a building is therefore not quite clear and the durability of materials is therefore a scientific area where the uncertainity today is large. It is, however, quite clear that the properties of the commonly used building plastics change significally during the time periods relevant to building. A qualified analysis of these effects - e.g. based on a service life time analysis - is today lacking.

The third set of problems which may break the expanding use of plastics in building is connected to the specific fire technical properties of these materials.

It is obvious that the fi e behaviour of modern building plastics cause major problems. These can be summarized under the following headlines.

a) High heat value - most plastics have calorific values of the same magnitude as oil, which means approximately twice the value for wood.

b) Heavy smoke production - the plastics produce large amount of smoke with high optical density.

c) Toxicity and corrosion - the materials do in some cases develop highly toxic on corrosive products of combustion. The most common example is represented by the hydrochloric acid produced at thermal decomposition of PVC.

d) Low thermal stability - large deformations when heated, formation of drops etc. may - for same plastic materials - create certain risks.

A special problem in this connection is the lack of relevant fire test methods. The existing methods were normally developed for testing traditional materials and have often turned out to give irrelevant results when testing plastics. Development of new methods is at present going on within the work of ISO (International Organization for Standardization).

Waste products' utilization

The raw material situation for the building materials industry is so far favourable with the exception of specific sectors (cf the previous section). However, increasing costs make alternative raw material sources interesting.

A general tendency in the modern, industrialized society is to utilize all rescøurces available as far as possible. The question of reusing industrial waste products forms a very interesting field of development in this connection. As an example can be taken some parts of the mineral processing industry which produces large volumes of waste products. These volumes represent considerable costs occuring from crushing, grinding and transports. These waste products could be used - and have been used in some cases - for building material purposes with good success.

One basic disadvantage of the natural minerals is that there tensile strength is normally low compared to the compressive strength due to unregularities in the structure of the material. One way to avoid this disadvantage is to crush the material - a process which is already done for many waste products - and to rebind the material e.g. with cement paste with or without hydro-thermal curing.

Research and development work in this field is going on in Sweden and abroad. Main attention has hitherto been paid to the $CaO - SiO_2 - H_2O$ combination as the binding mechanism in leight weight concrete is of this type. During the last years encourageing results have been reported from steam curing of Al_2O_3 and of the $MgO - SiO_2 - H_2O$ complex. Due to practically unlimited raw material stock of suitable Mg - minerals the latter is of special swedish interest.

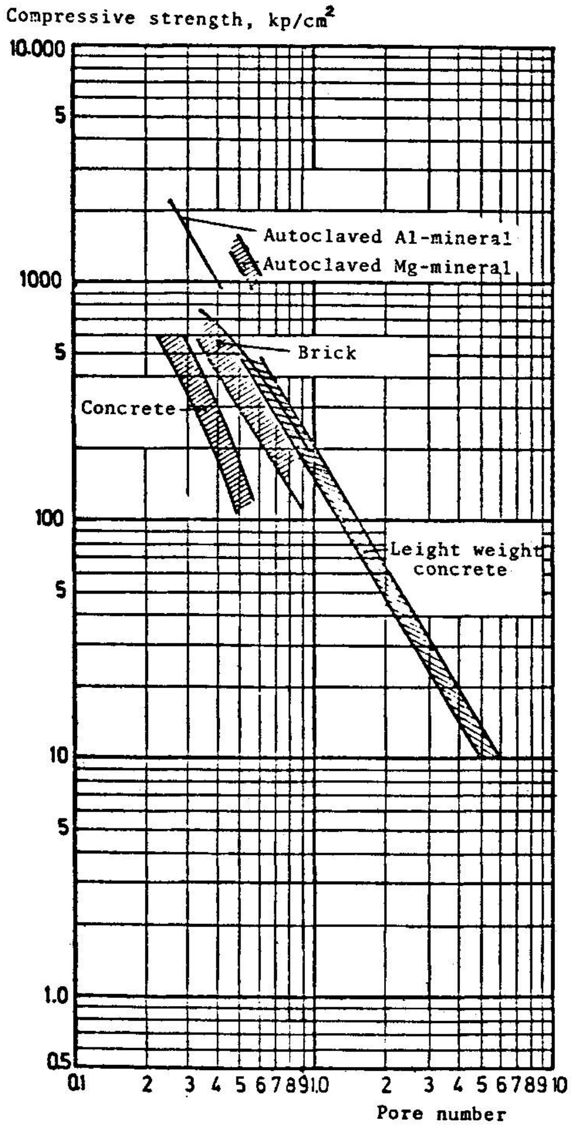


Fig. 7

Relation between pore number and compressive strength for some building materials and for experimental, autoclaved materials based on Aluminum and Magnesium minerals.

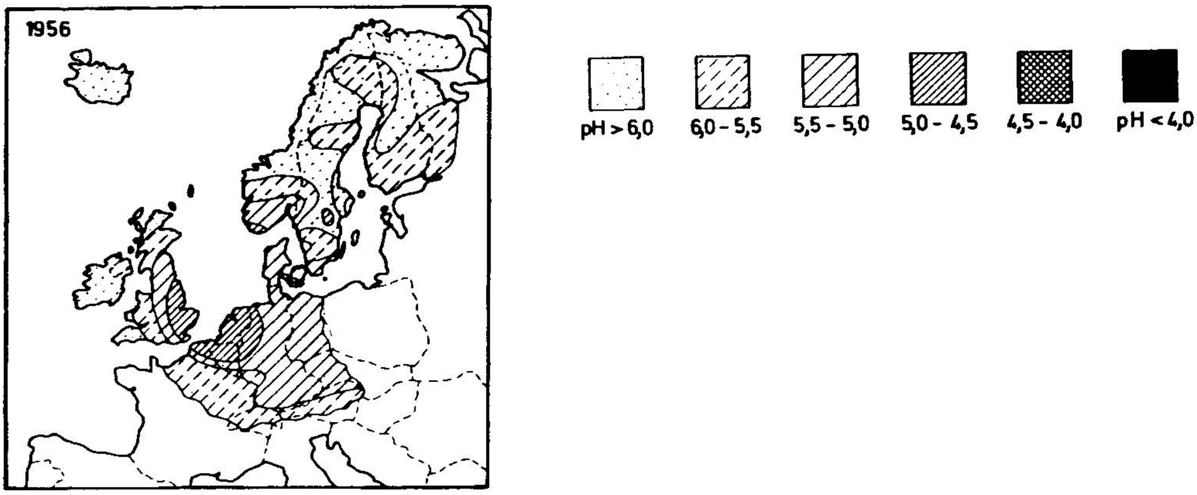
In fig. 7 is shown some examples on the relation between pore number and compressive strength for some materials included in swedish investigations /Kihlstedt, 1974/.

Environmental influences

All building materials are exposed to environmental influences of different kinds which may deteriorate the material. Most of them are well known and can be listed under the following headlines:

- Chemical (acid and alkalies)
- Electro-chemical (rust)
- Physical (effects of freezing water)
- Biological (micro organisms, fungi)

As a consequence of extensive polution of acid products - e.g. SO_2 - the environment of the industrialized parts of the world is getting increasingly aggressive. This is illustrated by fig. 8 in which the pH-value of the european rainfall is shown.



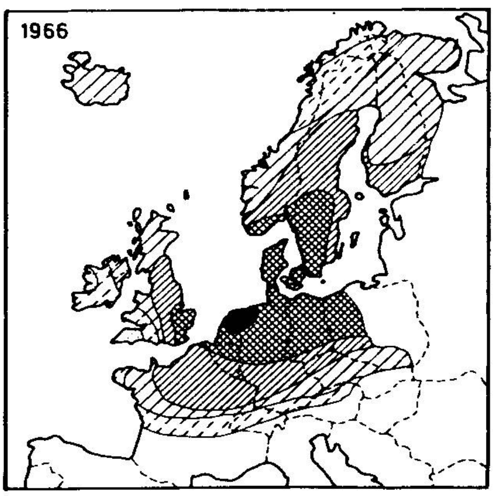


Fig. 8

Average pH-values (over one year) of the european rainfall.

It is easily understood that these low pH-values create a much more deteriorating climat for almost all materials than is the case in other parts of the world. One example is given in fig. 9 where the intensity of rusting is shown for test specimens in different environments.

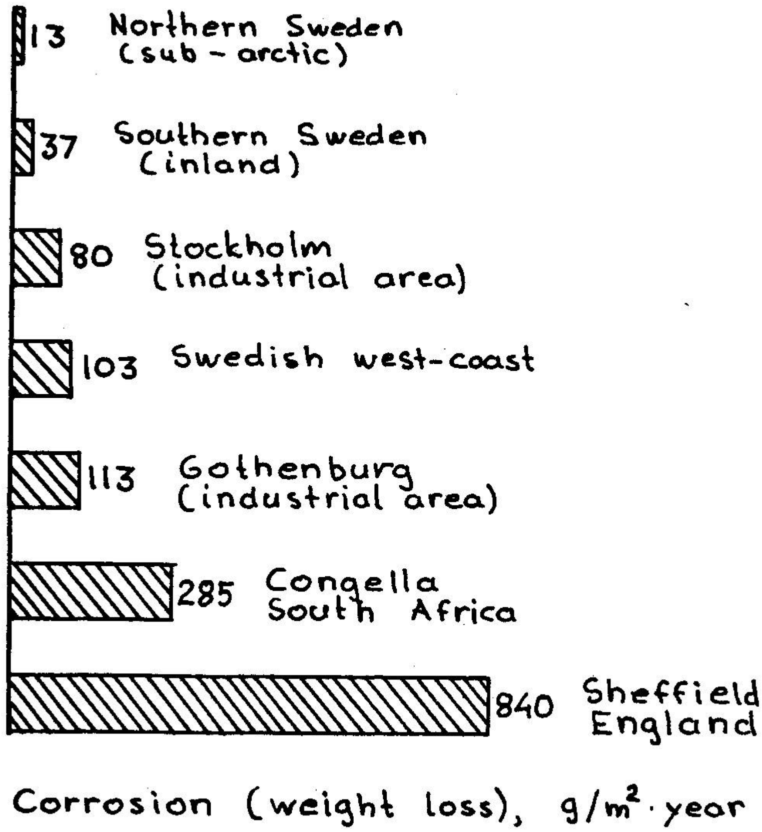


Fig. 9

Measured values of the corrosion (weight loss) for steel test specimens in different environments

In this paper have been given some fragmentaric aspects on the development of building materials against the background of trends i in building industry, raw materials supply, waste products utilization and environmental influences. Due to space restrictions essential and interesting parts of the subject have been deleted. However, I am convinced that the aspects which are mentioned in the paper are of major interest today and will be of still increasing interest in the future.

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