App 2/II

CONCRETE POLYMER COMPOSITES CLASSIFICATION

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All systems we are in our committee interested in are composite materials. About the complexity of composites, of their deformation and fracture behaviour and prediction of their properties it is not necessary to speak here. We all are aware of it.

There is existing a number of diverse mechanisms in the formation and application of composites. These mechanisms mutually intermingle, often synergically interact and we are only seldom sure what the individual mechanism means for the very investigated composite.

Therefore I handed over (or sent) to you the conception of a General theory of composites published in Euromech in Jablona, Poland, 1986, in which I tried to specify - on the basis of different analytic studies made around the world - the decisive criteria and the fields of their validity. It shows clearly that it is possible to analyse cohesive particular composite materials only if they are classified into three groups.

I suppose that all of you, if you didn't study it, at any rate read my text and I don't wish to recapitulate, the less to repeat it now. What I only want to underline here is the absolutely clear fact: primarily responsible for the behaviour of composites is their structure, more comprehensive their structures, that is microstructure of present matter(s), structure of present phases and superstructure of the material, of the system.

Allow me now to pass on to the concrete-polymer-composites more concretely in the light of the meant structural theory. (Fig. 1). What we are thinking mainly under C-P-C are PCC, PC, PIC, PIPC but also POC, PMC.

What are the main features of structure of the individual systems you can see in the figure.

It is also clear that the behaviour of this composite multiphase materials is the function:

- the properties of the phases, namely the property of the geometrically continuous matrix (bonding agent)
- volume representation of the matrix in the system
- porosity (voids) of the filler and volume representation of fluid phase (voids, pores) in the system
- mechanical (physical) and chemical interaction between the matrix and the filler (also in dependence on the conditions of the origin of the material) determining the <u>primary</u> state of internal stress of the system
- mechanical (physical) and possibly chemical interaction of the system with the ambient environment (loading, humidity, temperature, etc.) responsible for the <u>secondary</u> state of of internal stress.

Schematically we can record it, for example for PC, to the schema in Fig. 2. We can see among others that all five functions directly influence the short-time properties (mechanical, physical, chemical) of the composite material as well as they are (arising) owing to rised states of internal stress (primary and secondary, microfracture included), which together with properties specify long-term properties or performance of composite material.

The rate of validity or the mathematical weight of these functions depends on the structural arrangement of the respective system in the whole domain of composite materials, limited by nothing but the matrix on the one side and by the single filler on the other side, depending on the volume representation of both the solid parts (that is matrix and filler) in the overall volume (sum) of the solids in the system, as you can see for example of PC in the Fig. 3, or depending on the weight ratio of two solid parts of the system in the Fig. 4.

The domain of cohesive composite materials is - as you see - divided (or minimally could be divided) into three regions (or intervals) marked I. - II. - III. (Fig. 5).

The first of these three intervals is the interval of filled bonding agent. The filler in the system of this type (whether granular, lamelar of fibrous) is segregated (dispersed) in the matrix. With the exception of the cases when the matrix is porous in itself, the systems of this interval may be considered as compact fully filling given space v, that is $v = f + m$ (Fig. 6).

The mechanical actions in these systems which result preferably from the relations of geometric and physical parameters follow shear flows mechanisms along interphase boundaries mainly resulting in the changes of mechanical energy by dissipation into thermal energy or in mechanical energy used for the formation of new surfaces (cracks, microfractures) in the structure.

The last, third interval, on the other hand, is the interval of bonded fillers. The skeleton of the systems of this type consists in aggregate filler the particles of which are bonded by bridges of the matrix. Since the matrix does not by far suffice to fill all the voids of the aggregate filler, every system of this type is characterized beside closed porosity p_c by an open interior volume, by continuous porosity p_o, that is $v = f + m + p_o + p_c$ (Fig. 7).

If the continous porosity is filled additionally with a binder (e.g. by impregnation) (Fig. 8) we obtain a bi-structural system with much better properties that the initial one. The reason is namely the creation of an independent infrastructure in the pores of the primary matrix, geometrically arranged as if along fibers of microscopic diameters, with a large number of interfaces. The usual explanations of improvement, as a better cohesion of phases, chemical influencing of primary matrix, densification of the system, etc., are not quite correct as I have demonstrated by comparison of two systems with the same matrix volume in unit volume, once a PC with close porosity and the other case a PIPC system obtained by impregnation of the continuously porous PC (Fig. 9).

If the binder in the system is missing, being replaced by environmental medium, we obtain the composite material of the 4th type, which is noncohesive, e.g. soil (Fig. 10), that is $v = f + p_o$.

The deformation mechanism is <u>most complex</u> in systems of the second, intermediate or transition interval. The systems here are characterized also by <u>aggregated</u> filler and <u>closed</u> (discontinued) <u>porosity</u> varying from zero to a value which it is, however, impossible exactly to specify, that is $v = f + m + p_C$ (Fig. 11).

The mechanical actions in both the second and the third interval systems follow <u>direct force flows mechanism</u> resulting in the formation of force configurations in the structure (and, consequently, in the origin of loaded and relieved regions in the structure). Mechanical energy is used for the deformation of the inner skeleton (formed by force ways), the deformation of the elements of the skeleton, the failure of the skeleton and the failure of the elements of the skeleton.

Have a look now for principles of selection of filler and binder of PC.

The selection of filler has to ensure (Fig. 12)

- minimum porosity of filler
  - by at least three gradings
  - by at least 7 - 10 % (in weight) of microfiller
  - by gap-grading granulometric curve (gaps min. 40 of lower grade, max. diameter of grain about two diameters of min. grain in every grade)
- maximum size ~ 1/3 of minimum layer thickness
- cleanness, dryness, resistivity to binder
- properties of filler according to the PC properties asked.

The selection of binder (Fig. 13) depends from <u>technical</u> point of view on fundamental technological properties and technical properties after hardening, from the <u>economical</u> point of view on the type of parent raw material. We could of course after present knowledges state <u>many</u> of other quality and quantity parameters in order to optimize the system in accordance to intended use. We could also in many directions foresee the future development. But for the moment, for justifying superiority of structural approach as well as the beginning of discussion, I hope it was said enough.

What conclusions can we accept:

1/ The determined factor for the description of all the systems contained in C-P-C is the structure(s)

2/ Not all is clear, namely in the description of damage processes in the structure(s)

3/ The criteria for classification, description are

<u>main</u> - structural

<u>auxiliary</u> (second, helping)

- chemical (nature of the matrix, components properties, interphase reactions, solidification way, etc.)
- technological (of manufacturing)
  - . main process (mixing, impregnation)
  - . after placing operations. (densifying)
  - . condition of solidification
- serviceability (durability), mechanical, other physical, chemical properties

At the very end of my speech I'd like to draw your attention to the fact that out Committee is not my first try to contribute to a systematic knowledge about composites. In 1982, after ICP/RILEM/IBK Symposium, I tried to create an international team of experts for attaining this object. The basic materials have been worked out, the written discussion has only begun but has never been closed. The reasons were:

1/ the most members had not time enough to study and correspond

2/ it was difficult for a series of members to participate in such a team if it was not in the frame of any international organization.

Many members of our committee were also members of the mentioned team and have the materials. For the others I have a copy here and further eight ones I can send additionally.

I think it suitable to enclose these materials in the bases of the work of our committee.

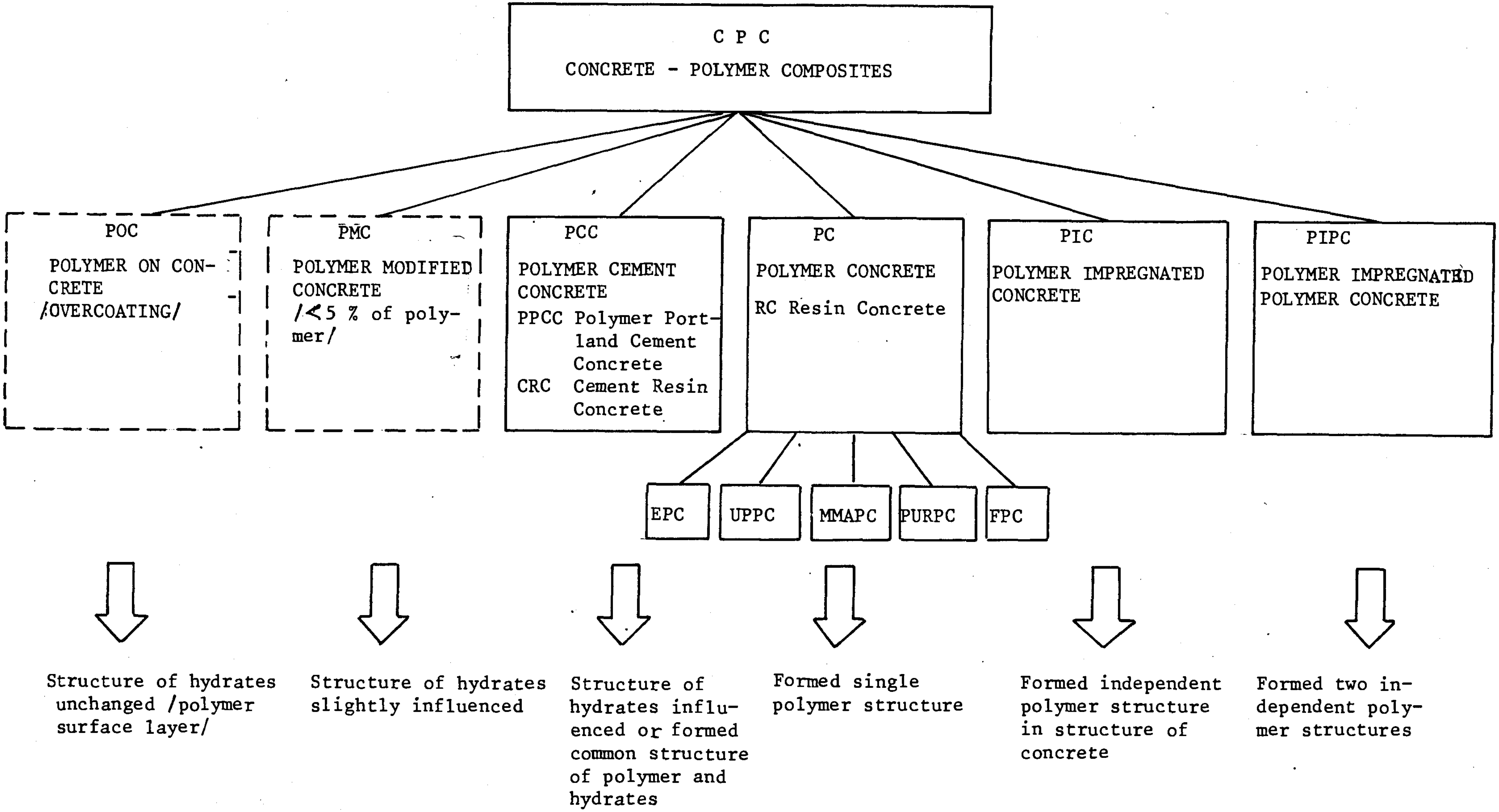


Fig. 1 Terminology in Concrete-Polymer Composites

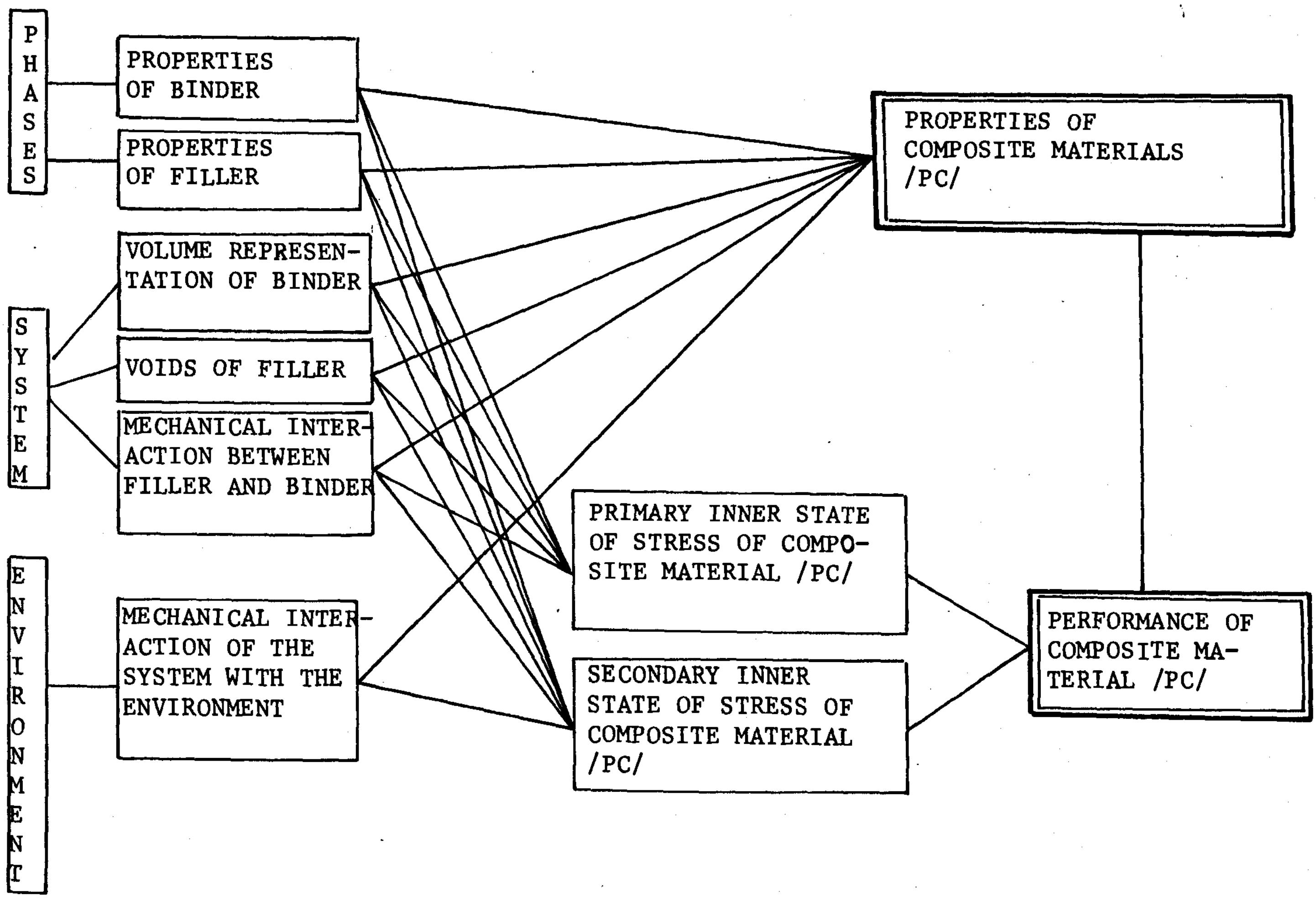


Fig. 2 Properties and performance of PC as functions of original parameters

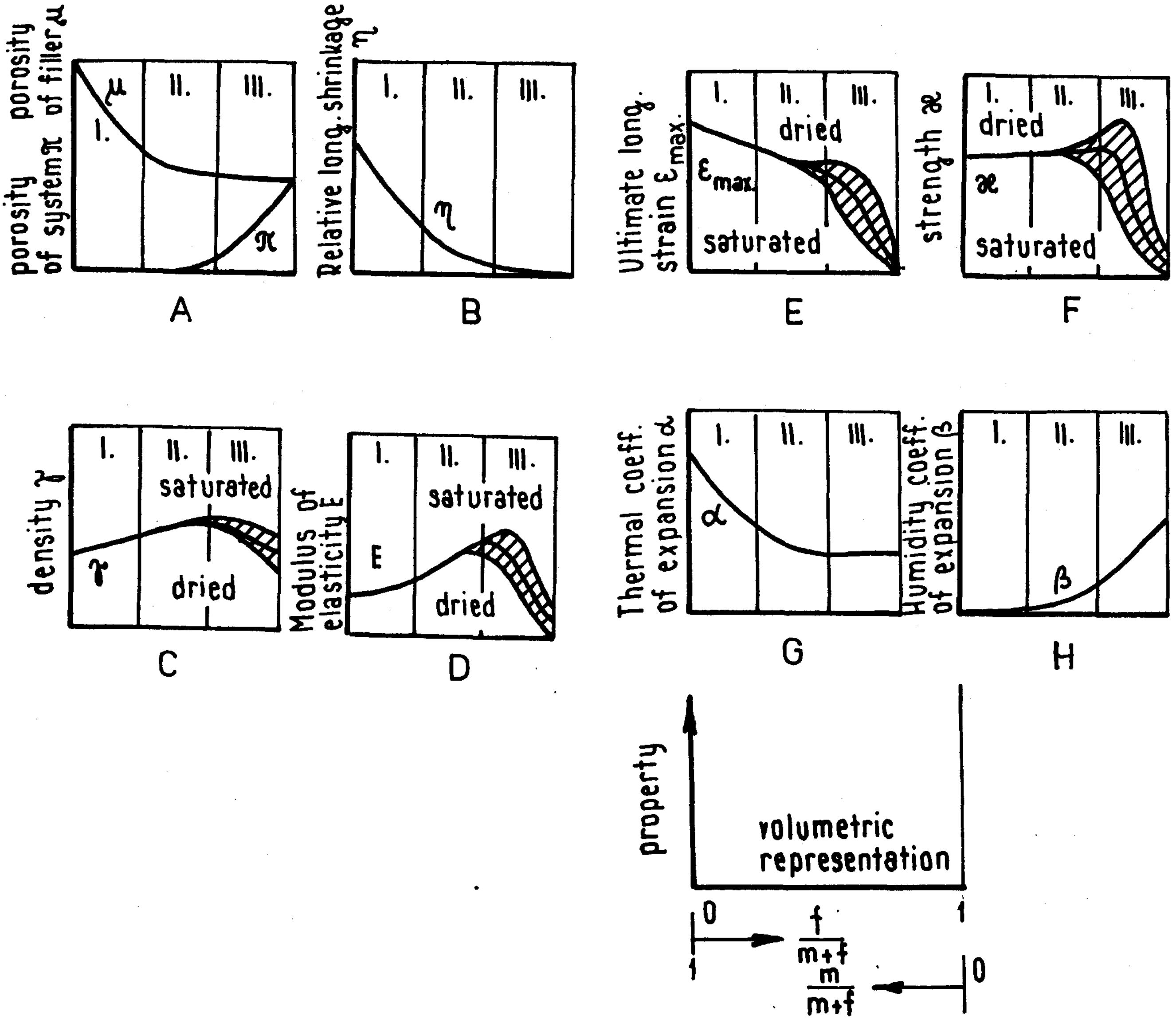
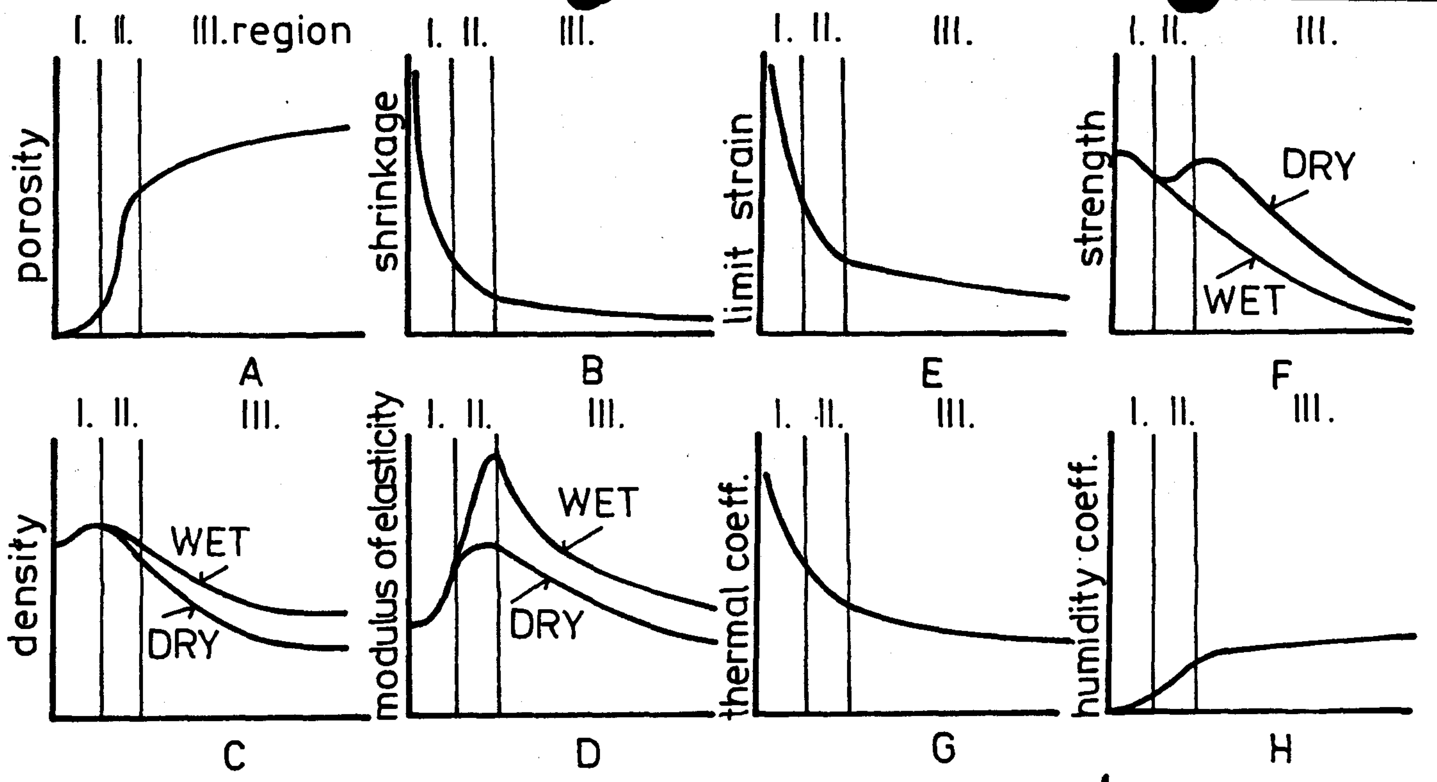


Fig. 3 Properties of possible systems of two solid phases with or without the presence of a fluid phase in dependence on volume representation of phases in unit volume



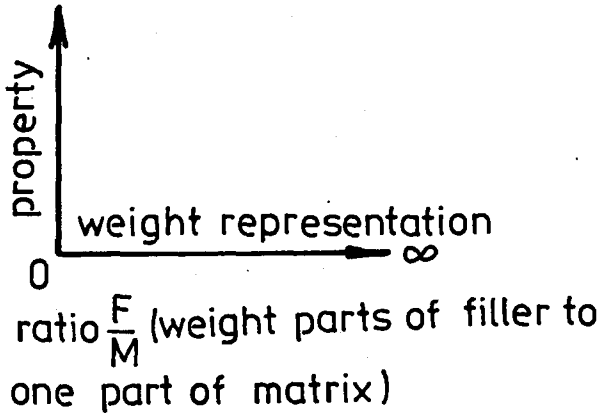


Fig. 4 Properties of possible systems of two solid phases with or without the presence of a fluid phase in dependence on the ratio /by weight/ of the solid phases

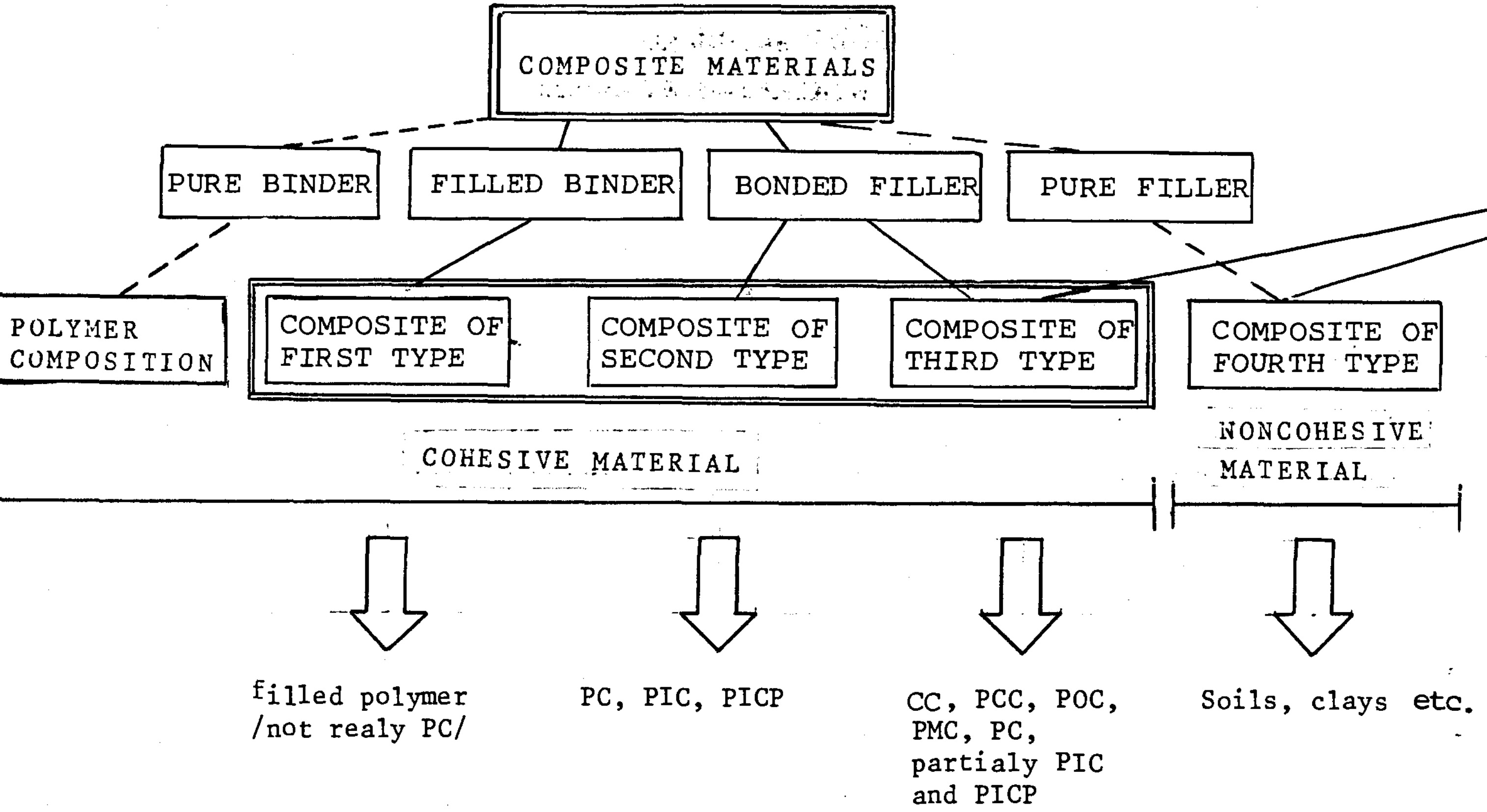


Fig. 5 Fundamental Types of Composite Materials

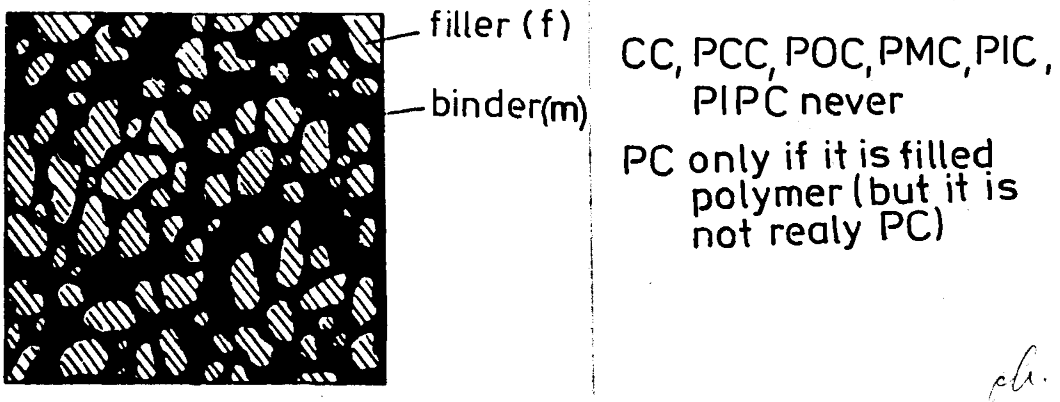


Fig. 6 Composite material of first type

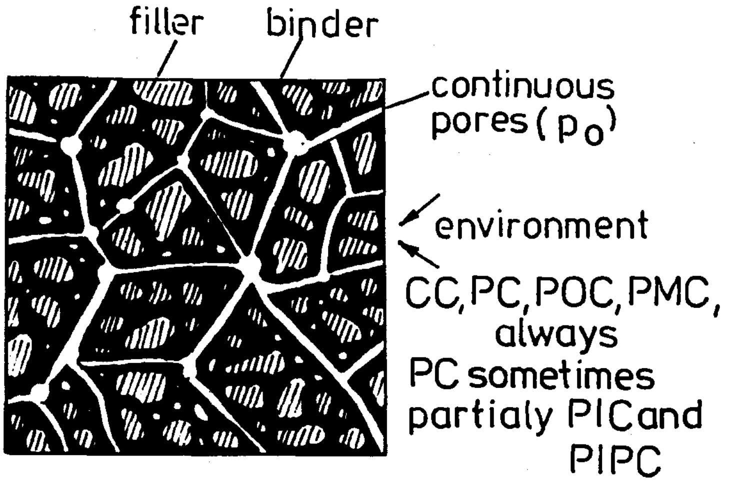


Fig. 7 Composite material of third type

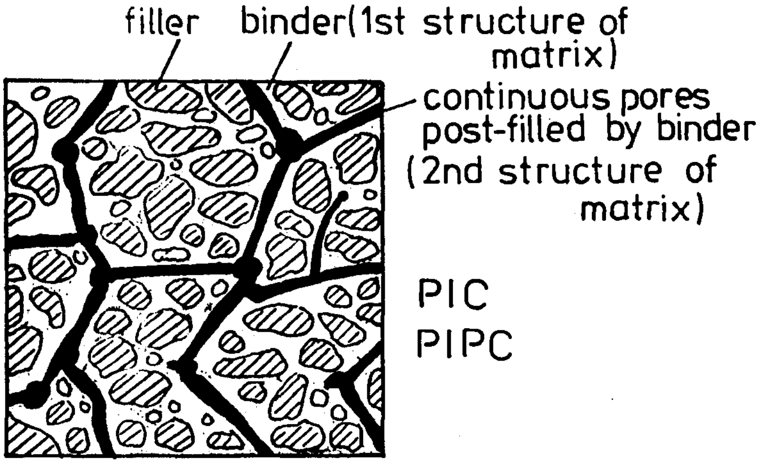


Fig. 8 Bistructural composite system

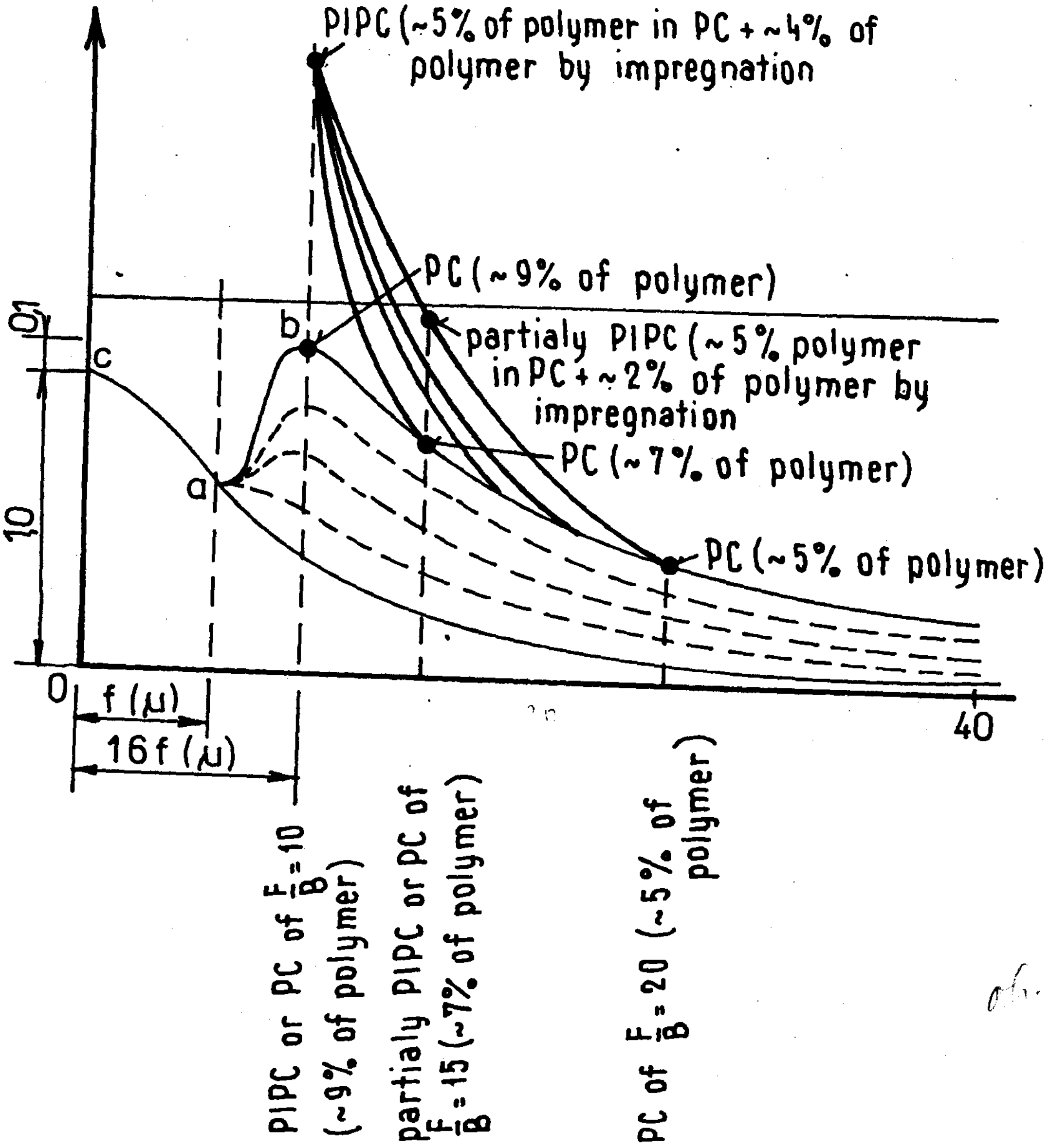


Fig. 9 Change of strength of PC after impregnation by the same polymer /PICP/ plotted against the ratio /by weight/ of solid phases

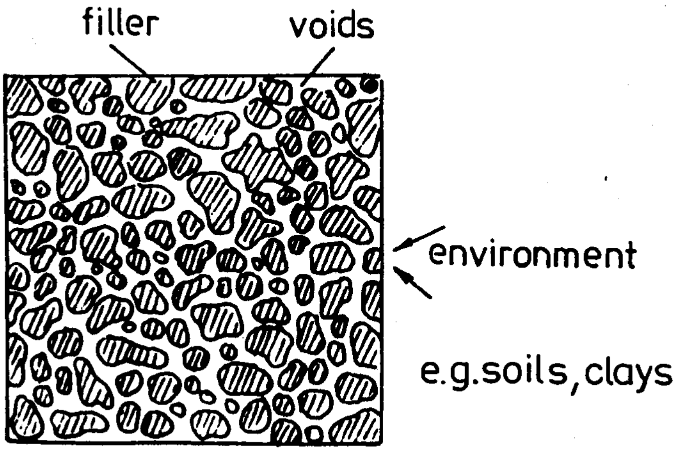


Fig. 10 Composite material of forth type

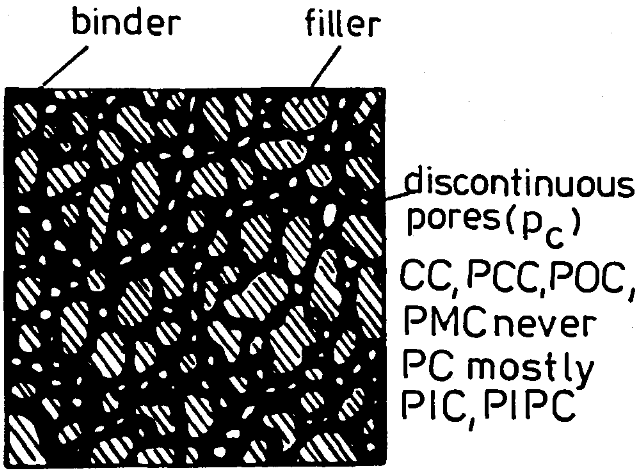


Fig. 11 Composite material of the second type

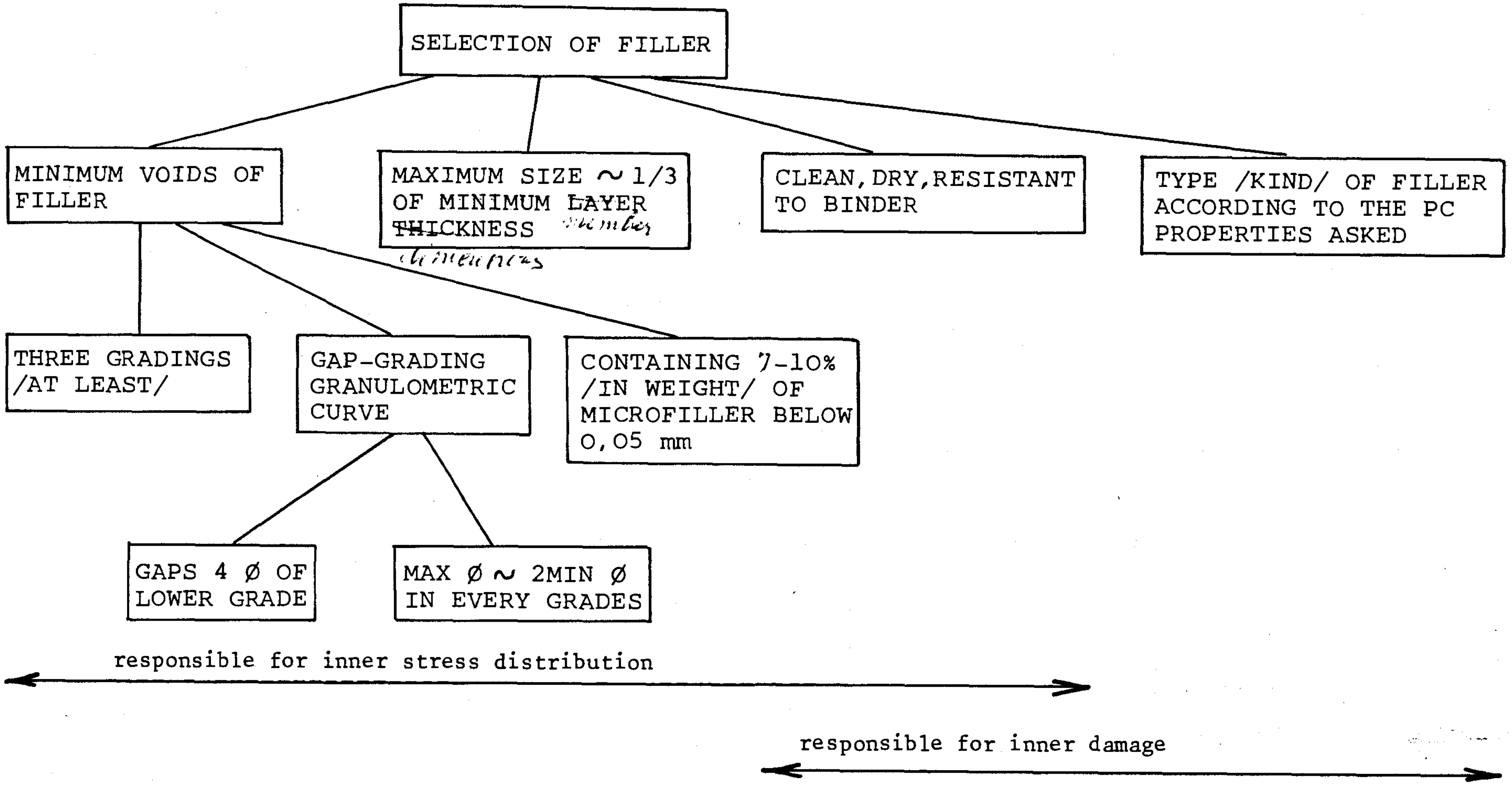


Fig. 12 Crieteria for Selection of PC - filler

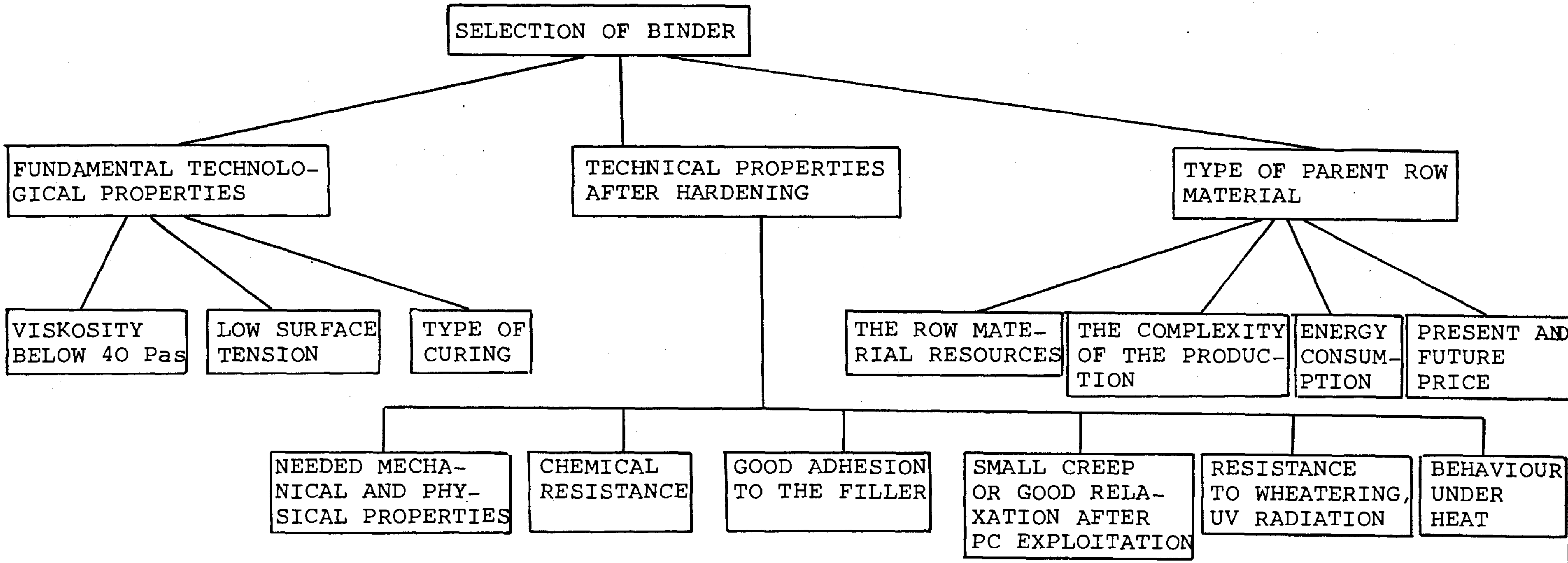


Fig. 13 Criteria for Selection of PC - binder

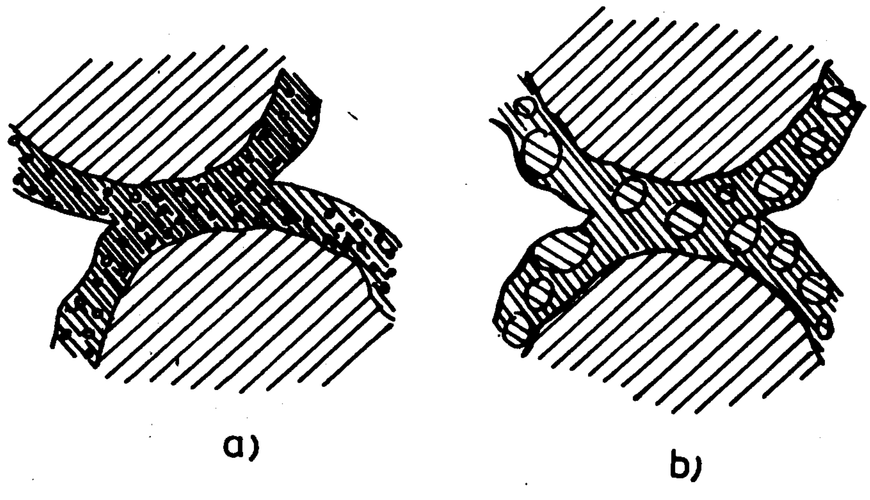


Fig. 14 Correct /a/ and uncorrect /b/ particle size of microfiller in accordance to the thickness of the layer of the binder enveloping the particles of the basic filler

RESIN	ABBR.	TYPE OF CURING	VISCOSITY /Pa s/
Unsaturated polyester	UP	Polymerization	0,1 - 10
metacrylate	MMA		0,002-0,15
epoxy	E	Polyaddition	2 - 40
polyurethane	PUR		0,1 - 10
epoxyasphalt	EA		20 - 40
furylalkohol	FOL	Polycondensation	
furylalkohol/ furylaldehyd	FOL-FAL		0,002 - 30
furylaceton	FA		

Suitable resins for the binder of PC

App. 4/II

C-PC CLASSIFICATIN CRITERIA

Draft 1

Main criterium
- structure (structure types)
. mode I
. mode II
. mode III (IV)
. others (if any)

Auxiliary - first order criterium
- chemical nature of the material (chemical, material types)
. component properties
. interface reaction
. solidification way
. others

Auxiliary - second order criteria
- manufacturing process (technological)
. main process
.. mixing
.. impregnation
.. overcoating (?, POC)
.. others
. after placing treatment
.. designing was
.. conversion conditions
.. others
- serviceability and durability
.. physical properties
.. mechanical properties
.. chemical properties
. application

App 6/IV

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ABSTRACT

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