# STRENGTH MEASUREMENT OF POROUS BODIES AT ISOSTATIC PRESSURE CONDITIONS

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*It is pointed out in this contribution to the possibility to measure the strenghts of britle specimens at isostatic pressure conditions.*
*The measurements can be performed using mercury porosimeter after previous encapsulation of test specimens into the flexible rubber envelope.*

## INTRODUCTION

The mechanical strength of materials equal or like as cement composites, ceramics or metals is most usually determined as the compresive, tensile, or bending strengths on test specimens of defined geometry and at precisely defined conditions of the measurement.

The test specimen is strained by the axial tension intermediated by the cylindrical piston or some kind of the pressure transmitting slab.

In the area of ceramics and of binding materials there exists practically no information about the measurement of the mechanical strength of materials under isostatic pressure. There exist equally no suitable experimental devices to this purpose and correspondingly no test procedures were elaborated up to now.

In our previous work the procedure to measure the compresibility of ceramics powders at isostatic pressure conditions was suggested [1]. In recent contribution we point out also to the possibility to measure the compressive strength of suitable porous materials.

## EXPERIMENTAL

Ball shaped specimens were taken for experiments. The small bodies of cca 10 mm in diameter we cut out of the plaster slabs prepared by the hydration of the common plaster of Paris.

The slurries of different water/solid ratios were used in order to get differences in porosity of received bodies.

The samples were covered by the flexible layer of cca 1 mm by their dipping into the stabilized water dispersion of natural latex. After drying encapsulated samples were put into the pycnometer of the mercury porosimeter (Carlo Erba 1520). The measurements were performed in a way similar to the measurement of pore distributions with only difference that the container of the pycnometer was not vacuumed.

Paralelly the pore distribution was measured at the second set of the ball samples without their encapsulation. The fracture surfaces of plaster slabs were examined by the REM (Tesla BS 300).

*Table I*

Labeling of samples, their water/solid ratios and mean pore size

| Sample | $w/(w+s)$ | $r/\mu m$ |
|---|---|---|
| 1 | 0.4 | 1.5 |
| 2 | 0.426 | 2.3 |
| 3 | 0.454 | >3 |
| 4 | 0.5 | >3 |
| 5 | 0.571 | >3 |

## RESULTS AND DISCUSSION

Characteristic curves were obtained in the measurement which are shown in Fig. 1. As can be seen from them the volume of specimens is nearly without change up to the pressure which represents their strength limit. The collaps of the skeleton takes place

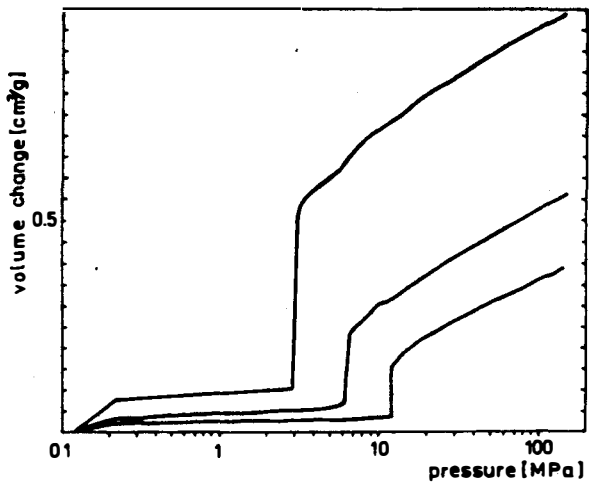


*Fig. 1. Characteristic curves of volume changes of plaster specimens at their deformation at isostatic pressure.*

in the narrow interval of pressures (practically isobarically). The change in the volume of specimens at collapses of their structures is proportional to their original porosity.

The dependence of the (bulk) porosity of specimens on the water/solid ratio of plaster slurries is shown in Fig. 2.

The results of strength measurements are given in Fig. 3. The very good reproducibility of results was achieved only at the sample No. 5, which shows the lowest mean diameter of pores.

The deviation of strength data is a result of the statistical nature of the strength characteristics of the brittle bodies.

By present measurements the strength in "microvolumes" of particular bodies (slabs of the plaster of Paris) is determined. The strength deviation is increased approaching the lower water ratios. One of the main reasons to the strength deviation at individual measurements is increased mean pore size of test specimens (in spite of the decreased total volume of pores). The absolute strength values are influenced also by other factors as the residual humidity of specimens, their ageing, etc. With decreased water/solid ratio also the slurry viscosity increases and workability of the slurry is diminished.

Inspection of fracture surface (REM) revealed the presence of spherical macropores in samples 1 and 2 respectively, what indicates the presence of remnant air bubles in casted plaster slabs.

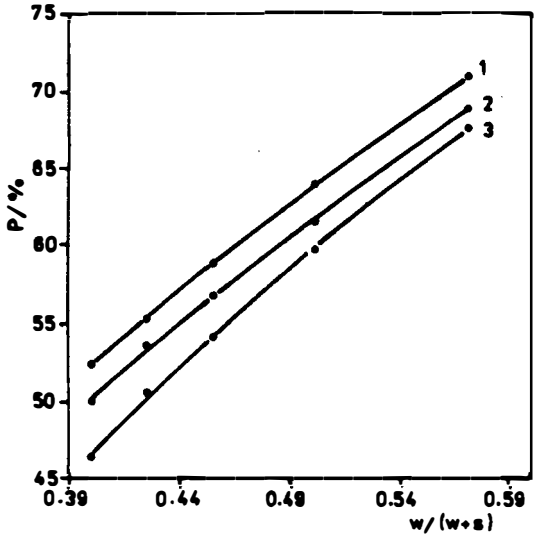


*Fig. 2. The dependence of bulk porosity of test specimens on water/solid ratio of plaster slurries: 1 – the volume of pores is calculated according to the formula P = (w-0.13)/(w+0.36) [4]; 2 – the volume of pores determined by mercury porosimetry; 3 – the volume of pores determined from measured volume of samples by buoyancy force measurement in mercury [5].*

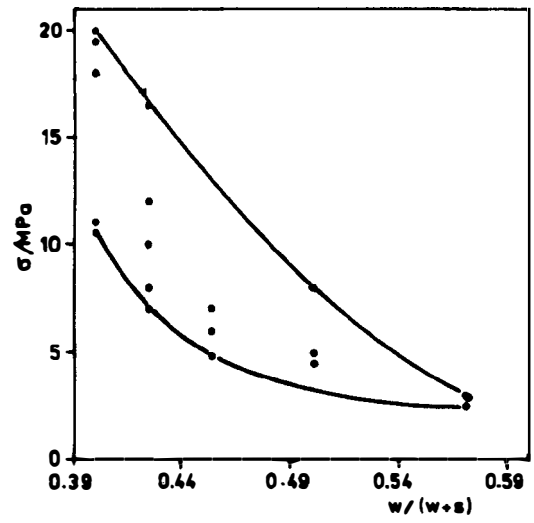


*Fig. 3. The dependence of the strength of test specimens on the water/solid ratio of plaster slurries.*

The curve in Fig. 3 limiting the strength area from the upper side declares, with the certain approximation, the strengths of the material which is close to its intrinsic strength, it means the strength of the bodies without the presence of macrodefects. The lower curve points to the character (the size) of the macrodefects in the volume of test specimens.

It is seen from Fig. 1 that volume change of specimens after collapsing of their primary structure is linear with the logaritm of the pressure what is usuall behaviour of ceramic powders at their pressing and is also in agreement with works [2, 3] in which the response of powder samples was studied at their pressing in steel dies.

In the cited work [2] the linear dependence in the interval of higher pressures was achieved by the correction taking into account the elasticity of the die. In the case of the present manner of measurements the mentioned corrections are not necessary.

On the basis of performed experiments it is possible to give only the partial insight into possibilities of the given method. For bodies deformed by the brittle fracture in order not to have too high scatter of strength values this procedure can be applied only to low defect structures with moderate strength and with sufficiently small pores.

The scope of materials which comes into account for the strength test in the proposed manner can include xerogels, plaster – like skeletal structures, powder granulates and possibly some pharmaceutic substances.

## CONCLUSION

The procedure to measure the mechanical strength by the application of the isostatic pressure is illus-

trated using the small test specimens from plaster of Paris.

The measurements were performed in mercury porosimeter after previous encapsulation of specimens into the flexible latex envelope. Such measurement can be applied to similar types of porous ceramic and other brittle materials.

## References

[1] Majling J., Kovár V., Hrabě Z., Khandl V.: Proc. Int. Conf. Engineering Ceramics '89 (edited by M. Haviar), 254, Veda Publ., Bratislava 1990.
[2] Matsumoto R. L. K.: J. Am. Ceram. Soc. *69*, C-246 (1986).
[3] Cooper A. R., Eaton L. E.: J. Am. Ceram. Soc. *45*, 97 (1962).
[4] Schiller K.: Nature *180*, 862 (1957).
[5] Figusch V., Haviar M., Pánek Z.: Silikáty *23*, 307 (1979).

## MERANIE MECHANICKEJ PEVNOSTI PÓROVITÝCH TELIESOK PRI VŠESTRANNOM TLAKU.

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V príspevku sa poukazuje na možnosť merania tlakovej pevnosti vzoriek materiálov s vhodnou pórovitosťou s využitím komerčných prístrojov – typu ortuťového porozimetra (napr. Carlo Erba 1520).

Skúšobné telieska v tvare blízkom guli priemeru cca 10 mm boli vyrezané zo sádrových dosiek. Sádrové dosky sa pripravili hydratáciou bežnej sádry. Vykonanými meraniami sa získali charakteristické krivky prezentované na obr. 1. Objem teliesok sa nemení až do dosiahnutia tlaku, ktorý vyvolá napätie zodpovedajúce medzi ich pevnosti. Rozrušenie skeletu teliesok prebehne v úzkom intervale tlaku (prakticky izobaricky). Zmena objemu telieska pri rozrušení jeho štruktúry je úmerná pórovitosti telieska.

*Obr. 1. Charakteristické krivky objemových zmien sádrových teliesok pri ich deformácii účinkom všestranného tlaku.*

*Obr. 2. Závislosť východiskovej pórovitosti skúšobných teliesok od vodného súčiniteľa sádrových kaší: 1 – objem pórov vypočítaný podľa vzťahu P = (w-0,13)/(w+0,36) [4]; 2 – objem pórov určený ortuťovým porozimetrom; 3 – objem pórov určený pomocou merania vztlaku teliesok v Hg [5].*

*Obr. 3. Závislosť mechanickej pevnosti skúšobných teliesok od vodného súčiniteľa sádrových kaší.*