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STRESS ON REINFORCING RIBS AND CONCRETE STRAIN FROM IN-SITU MEASUREMENT DURIGN SHAFT-SINKING BY FREEZING PROCESS

Summary. Artificial freezing process and reinforced concrete sandwich lining are applied in shaft sinking at Eastern Air Shaft of Panji Colliery No. 1 and at Western Air Shaft of Panji Colliery No. 2 in Panji Coal District with highly water-bearing Quaternary over-burdens 200-400 meters in thickness, composed of silt sand, fine-grained sand, moderately coarse sand, sand clay and effervescing clay.

Vibrating wire strain gauges, vibrating wire stress gauges and temperature gauges are embedded for in-situ measurement of reinforcing-rib stress and concrete strain. In this paper some results of the in-situ measurement are described.

Vertical reinforcing rib's stresses of the outher lining

Observation over the initial period shows that owing to the relative displacement of the lower end of the shaft lining and the face of the shaft a prestress is exerted on the vertical reinforcing ribs and again since the frozen ground behind the lining has moved towards the lower end of the shaft lining during the sinking of the next section, causing a sliding force of the shaft lining, and consequently the vertical reinforcing ribs start to bear a tensile stress. This is the reason for the stress acting on the reinforcing ribs to change from the compressive (See fig. 1 and fig. 2) state to the tensile state step by step. The results of the in-situ measurement testifies that the stress acting on the reinforcing ribs is not controlled by temperature, since its change with temperature is quite negligible according to the curve of the stress on the reinforcing ribs against the temperature as shown in fig. 1.

Annular reinforcing rib's stress of the outher lining

The stress of the annular reinforcing ribs consists of two stresses: the stress results from the action of freezing pressure and the temperature stress. When the load of the shaft lining is low, as in lower depths, is much lower, and the temperature stress becomes primary and the stress

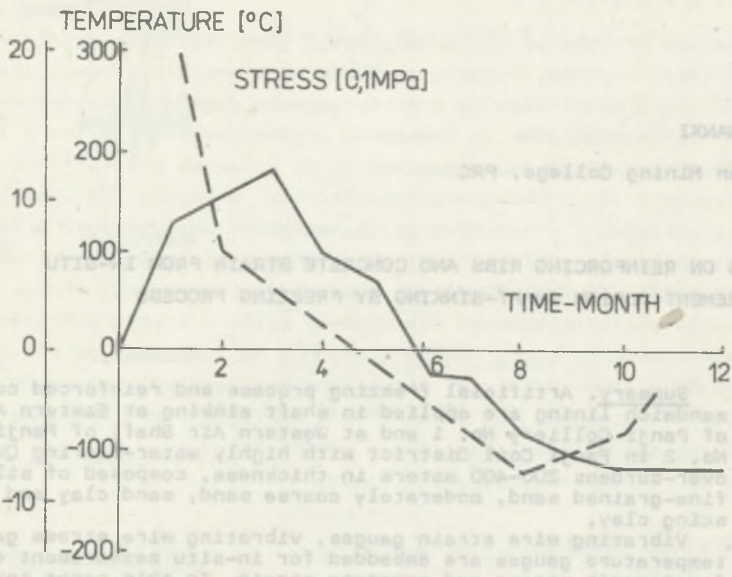

Fig. 1. Change in vortical reinforcing rib's stresses with time at 137 m depth in Eastern Air Shaft

Rys. 1. Zmiana czasowa naprężeń w pionowych żebrach wzmacniających na głębokości 137 m we wschodnim szybie wentylacyjnym

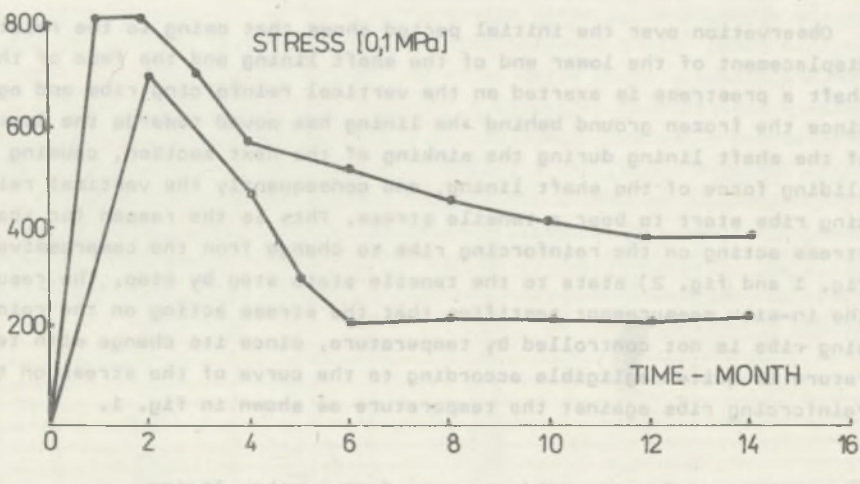

Fig. 2. Change in vertical reinforcing rib's stress with time at 120 m and 125 m depth in Eastern Air Shaft

Rys. 2. Zmiana czasowa naprężeń w pionowych żebrach wzmacniających na głębokości 120 m i 125 m we wschodnim szybie wentylacyjnym

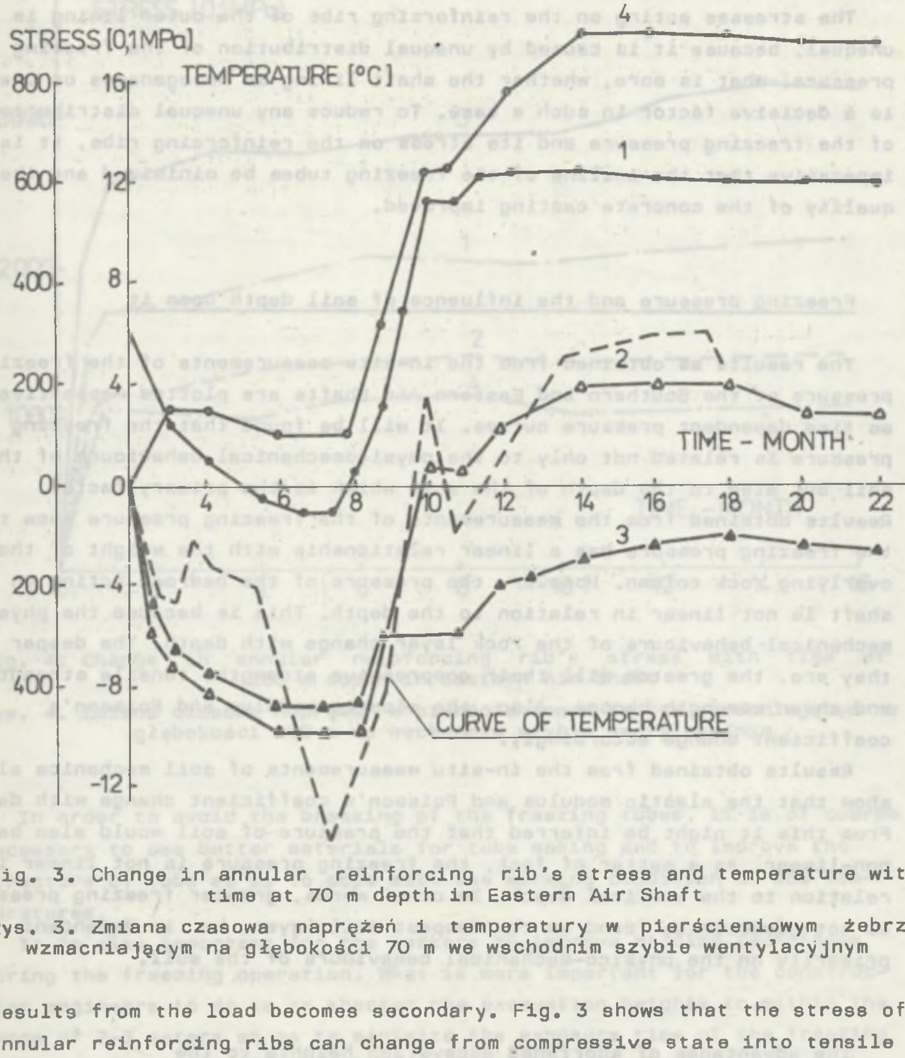

Fig. 3. Change in annular reinforcing rib's stress and temperature with time at 70 m depth in Eastern Air Shaft

Rys. 3. Zmiana czasowa naprężeń i temperatury w pierścieniowym żebrze wzmacniającym na głębokości 70 m we wschodnim szybie wentylacyjnym

results from the load becomes secondary. Fig. 3 shows that the stress of annular reinforcing ribs can change from compressive state into tensile state at low temperatures, but when the temperature rises it changes from the tensile state into the compressive state. Never-theless, the freezing pressure does not change obviously and the pressure is low (See fig. 4). In the case of greater depths, since the freezing pressure is greater, the influence of temperature is relatively not so notable. The stress on the reinforcing ribs does have changes, but then the degree of change is negligible.

Fig. 4 gives the curves of the stress acting on the reinforcing ribs. The curves are those of the freezing pressure at the same position as shown in fig. 5.

The stresses acting on the reinforcing ribs of the outer lining is unequal, because it is caused by unequal distribution of the freezing pressure. What is more, whether the shaft lining is homogeneous or uneven is a decisive factor in such a case. To reduce any unequal distribution of the freezing pressure and its stress on the reinforcing ribs, it is imperative that the incline of the freezing tubes be minimized and the quality of the concrete casting improved.

Freezing pressure and the influence of soil depth upon it

The results as obtained from the in-situ measurements of the freezing pressure at the Southern and Eastern Air Shafts are plotted respectively as time dependent pressure curves. It will be found that the freezing pressure is related not only to the physicomechanical behaviours of the soil but also to the depth of the soil which is the primary factor. Results obtained from the measurements of the freezing pressure show that the freezing pressure has a linear relationship with the weight of the overlying rock column. However, the pressure of the bedrock acting on the shaft is not linear in relation to the depth. This is because the physico-mechanical behaviours of the rock layer change with depth. The deeper they are, the greater will their compressive strength, tensile strength and shear strength become. Also, the elastic modulus and Poisson's coefficient change accordingly.

Results obtained from the in-situ measurements of soil mechanics also show that the elastic modulus and Poisson's coefficient change with depth. From this it night be inferred that the pressure of soil would also be non-linear. As a matter of fact, the freezing pressure is not linear in relation to the vertical depth. In other words, greater freezing pressure is not necessarily found in the deepest soil layer, but is dependent primarily on the physico-mechanical behaviours of the soil.

The advantages of shortened excavation heights to the prevention of breaking of freezing tubes

During the sinking operations of the Southern and Eastern Air Shafts in the No. 2 Colliery, Panji, Anhui, construction work was hampered due to the repeated accidents of breaking of the freezing tubes. It has been found that the stress acting on the freezing tubes are as follows: the tensile force caused by the longitudinal displacement of the soil layers, the temperature stress produced by the temperature field, and the bending stress acting on the freezing tubes caused by the displacement of the shaft wall during the shaft-sinking operation.

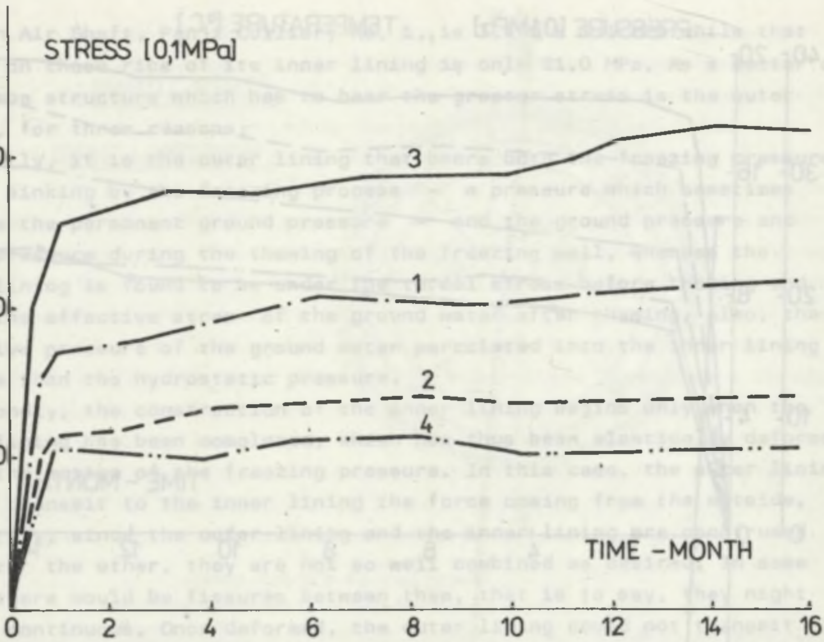

Fig. 4. Change in annular reinforcing rib's stress with time at 280 m depth in Eastern Air Shaft

Rys. 4. Zmiana czasowa naprężeń w pierścieniowym żebrze wzmacniającym na głębokości 280 m we wschodnim szybie wentylacyjnym

In order to avoid the breaking of the freezing tubes, it is of course necessary to use better materials for tube making and to improve the structure of tube so as to cope with the working condition at low temperatures.

It is also important for the workers to improve welding techniques during the freezing operation. What is more important for the construction engineers to do is to shorten the excavation heights to within the range of 2-3 meters so as to minimize the exposure time of the freezing wall and especially to strictly control the radial displacement of the freezing wall to reduce the bending stress acting on the freeztubes. Also, the freezing wall should be formed by strictly carrying out the freezing design: in no case should the freezing wall be allowed to be weakend.

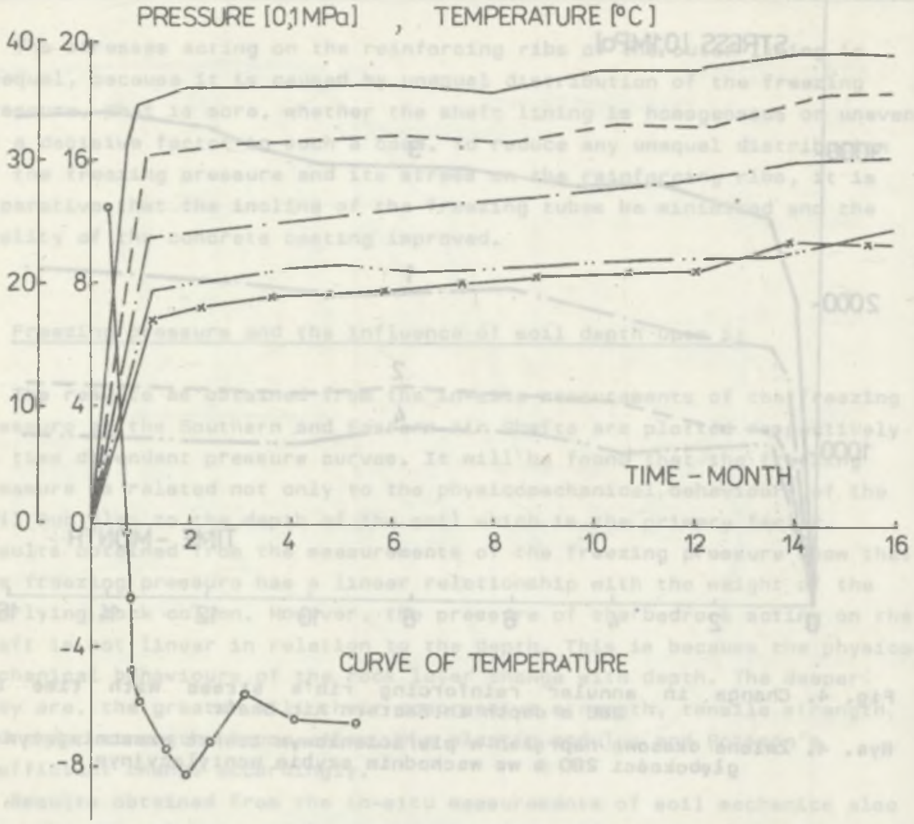

Fig. 5. Change in freezing pressure with time at 278 m depth in Eastern Air Shaft

Rys. 5. Zmiana czasowa ciśnienia mrożenia na głębokosci 278 m we wschodnim szybie wentylacyjnym

Interaction of the inner and outher lining of reinforced concrete sandwich lining

In designing the reinforced concrete sandwich lining, some engineers are apt to take it that it is entirely subject to the ground pressure and the water pressure from outside. According to this postulation, values obtained from stress analyses would be greater for the inside wall of the inner lining than for the outer lining. Field measurements, however, have failed to support this postulation. It has been found that the stress acting on the annular reinforcing ribs of the outer lining is much greater than the stress acting on those of the inner lining. For instance, the maximum stress acting on the reinforcing ribs of the outer lining at the

Eastern Air Shaft, Panji Colliery No. 1, is 3.170 x 0.1 MPa while that acting on those ribs of its inner lining is only 21.0 MPa. As a matter of fact, the structure which has to bear the greater stress is the outer lining, for three reasons:

Firstly, it is the outer lining that bears both the freezing pressure durign sinking by the freezing process - a pressure which sometimes exceeds the permanent ground pressure - and the ground pressure and water pressure during the thawing of the freezing wall, whereas the inner lining is found to be under the termal stress before thawing and under the effective stres of the ground water after thawing. Also, the effective pressure of the ground water percolated into the inner lining is less than the hydrostatic pressure.

Secondly, the construction of the inner lining begins only when the outer lining has been completed, which has thus been elastically deformed under the action of the freezing pressure. In this case, the outer lining cannot transmit to the inner lining the force coming from the outside.

Thirdly, since the outer lining and the inner lining are construced one after the other, they are not so well combined as desired. In some cases there would be fissures between them, that is to say, they night not be continuous. Once deformed, the outer lining could not transmit all the forces it is boaring to the inner lining.

These are the three aspects which account for the lower stress acting on the reinforcing ribs of the inner lining.

Concrete's strain of the outer lining

Four vibrating wire strain gauges were embedded inside the outer reinforced-concrete shaft lining at a vertical depth of 185 m (designated as the third level for observation) and were disposed at four different sites as shown in fig. 6. It has been found that the strain values increased rapidly since the embedding till after 20 days or so when they become stable (fig. 7). The value obtained from the respective gauges over the stable period range from 1.500 x 10^{-6} to 3.000 x 10^{-8}. In table 1 are listed not only the number of days from the embendding of the gauges to the beginning of the stable period but also the maximum and the minimum strain values obtained by all the sensing elements over the stable period.

The strain curve and the temperature curve as plotted in fig. 7 show that at the period during which the temperature of the shaft lining rose sharply the strain values for concrete were temperature-independent for they kept rising slowly, whereas the freezing pressure tended to fall at this observation level, showing that the freezing pressure decreased as the temperature increased, especially at the period during which the temperature rose from -5^{o}C to +10^{o}C.

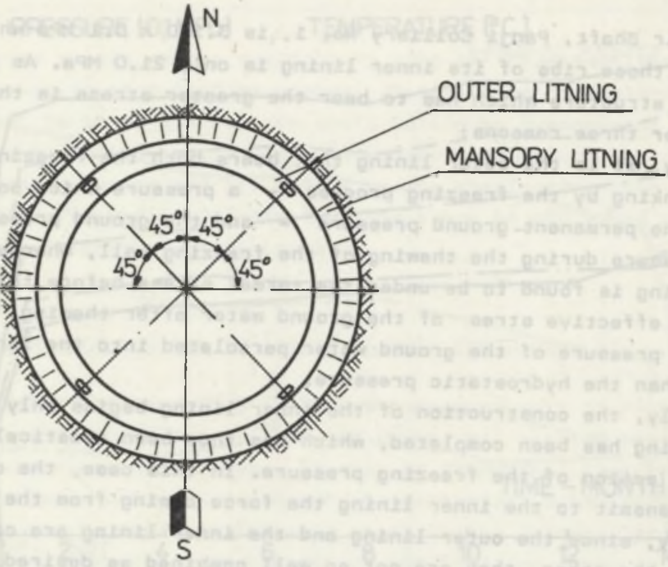

Fig. 6. Position of strain gauge
Rys. 6. Położenie czujnika tensometrycznego

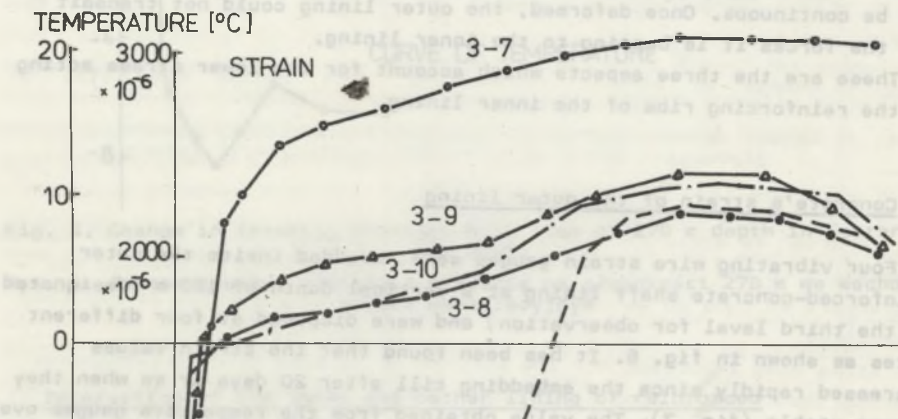

Fig. 7. Change in concrete-strain with time at 185 m depth in Westren Air Shaft
Rys. 7. Zmiana czasowa odkształceń w betonie na głębokości 185 m w zachodnim szybie wentylacyjnym

It has also been found that there are no marked differences between the maximum strain values given by the four different strain gauges, revealing that the non-homogeneity of the internal forces measured on the spot of the outer shaft lining is comparatively small (see table 1). Besides, the strain values obtained at the later stage tendend to decrease, which, in our opinion, is closely related to the following construction technology for the sandwich structure of shaft lining: before the freezing wall thawed out, the external cracks in the plastic layer in between the two reinfored-concrete shaft linings had been filled with cement grout whose pressure moved outwardly from the centre of the shaft towards the shaft wall along the inner edge of the outer shaft lining, whereas the external forces of the outer edge of the outer shaft lining were directed inwardly towards the centre of the shaft, so that the pressure (stress) from the outer shaft lining must have been reduced, so much so that the strain values as seen from the strain gauges become smaller correspondingly. Only after the freezing wall had completely thawed out did the water pressure act on the waterproof plastic layer.

Annular reinforcing rib's stresses of the inner lining

The third and fifth observation levels were arranged for measuring the stresses of the reinforcing ribs inside the inner shaft lining. The measurement results of the stresses of the reinforcing ribs obtained at the fifth level of observation are as follows: For a period of 25 to 45 days after the embedding of the gauges, the reinforcing ribs began to be tensioned and their stresses decreased gradually, after which the reinforcing ribs were kept in tension. During cement grouting before the thawing of the freezing wall had started, the reinforcing ribs originally in tension soon come under the pressure of the cement grout, as shown in fig. 8.

The tension stress values were found to be 20.0-34.0 MPa in general, while the values of the stress of the reinforcing ribs turned out to be 40.0-50.0 MPa. After the freezing walls had thawed out, the stress maintained at the inner shaft lining during cement grouting began to increase, but tended to stabilize eventually. Since the freezing wall thawed gradually, and the osmotic pressure of water increased steadily, the stress of the reinforcing ribs also went up slowly until it reached the value of 1.00 MPa or so.

According to the changes in stress recorded at the reinforcing ribs, the whole process may be divided into three stages (represented by three stress curve sections respectively): the stage at which the stress came under the influence of temperature, the stage characterized by stress increase, and the stage charadterized by stress stabilization.

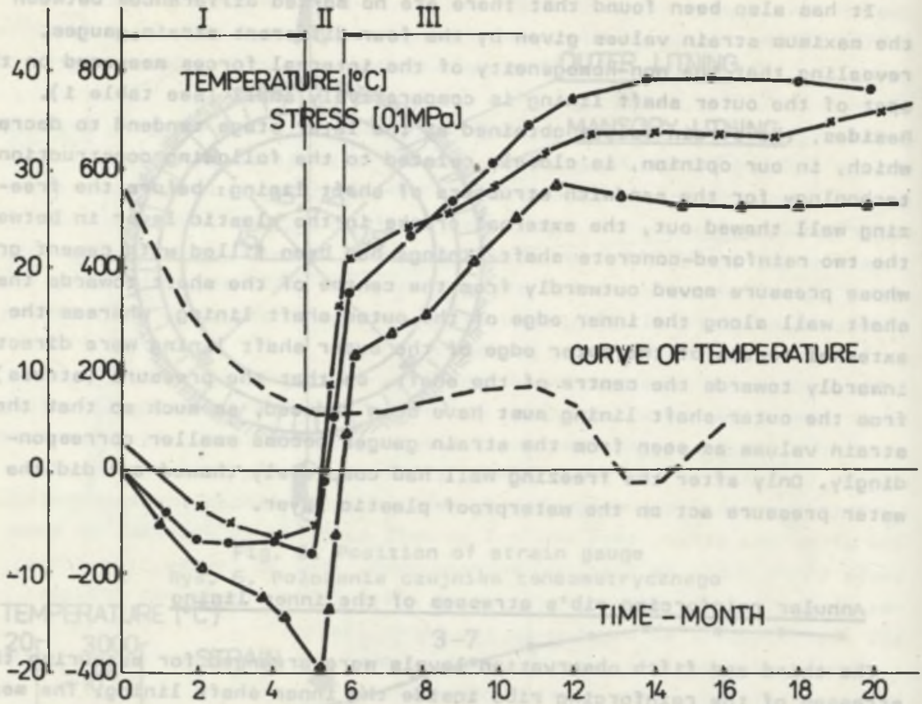

Fig. 8. Change in annular reinforcing rib's strain with time at third observation level

Rys. 8. Zmiana czasowa odkształceń w pierścieniowym żebrze wzmacniającym na trzecim poziomie obserwacyjnym

Table 1

Results of in-situ measurement for concrete strain

Observation level No	Depth of soil (M)	Soil type	Concrete strain gauge No	Minimum strain values over the stable stage ($\times 10^{-3}$)	Maximum strain values over the stable stage ($\times 10^{-3}$)	Number of days lasted from embedding of the gauges to the beginning of the stable stage
3	185	clay	3-7	1.539	3.10	7
3	185	clay	3-9	1.80	2.38	30
3	185	clay	3-10	1.618	2.35	30
3	185	clay	3-3	1.56	2.26	20

The data obtained show that the stresses of the reinforcing ribs caused by the pressure of cement grout were 40.0-53.0 MPa while the stresses caused by water pressure were 60.0 MPa. The stresses of the rinforcing ribs as a whole were less than 100.0 MPa. From this it may well be inferred that both the cement grout pressure and the water pressure should be brought into consideration while designing the inner shaft lining of a sandwich structure with a plastic layer in between to be constructed by the freezing process and the cement grouting method. Cement grouting, if not to be applied, or if employed only after the freezing wall has thawed out, will limit the design considerations in this respect to hydrostatic pressure.

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Recenzent: Prof. dr hab. inż. Mirosław Chudek

Wpłynęło do Redakcji w czerwcu 1988 r.

NAPRĘŻENIE NA FAŁSZYWYCH ŻEBERKACH (PRĘTACH WZMACNIAJĄCYCH) I ODKSZTAŁCENIE BETONU Z POMIARÓW IN SITU PODCZAS GŁĘBIENIA SZYBU PROCESEM ZAMRAŻANIA

S t r e s z c z e n i e

We wschodnim szybie wentylacyjnym kopalni Panji Nr 1 i w zachodnim szybie wentylacyjnym kopalni Panji nr 2 w Okręgu Węglowym Panji o wysoce wodonośnych czwartorzędowych nakładach o grubości 200 do 400 m złożonych z piasku iłowego, piasku drobnoziarnistego, średnio grubego piasku, piaszczystego mułu i burzącego się mułu stosuje się proces sztucznego zamrażania i obudową przekładaną ze zbrojonego betonu.

Drgające druciane przyrządy pomiarowe odkształceń, drgające druciane przyrządy pomiarowe naprężenia i przyrządy pomiarowe temperatury są wbudowane do pomiarów in situ naprężeń w fałszywych żeberkach (wzmacniających) oraz do odkształceń betonu. W artykule podano niektóre wyniki pomiarów in situ.

НАПРЯЖЕНИЕ В ФАЛЬШИВЫХ РЁБРАХ (УКРЕПЛЯЮЩИХ СТЕРЖНЯХ)
И ДЕФОРМАЦИЯ БЕТОНА, ПОЛУЧЕННЫЕ ВО ВРЕМЯ ИЗМЕРЕНИЙ
НЕПОСРЕДСТВЕННО ВО ВРЕМЯ УГЛУБЛЕНИЯ СТВОЛА ПУТЁМ ЗАМОРАЖИВАНИЯ

Р е з ю м е

В восточном вентиляционном стволе шахты Панйи № 1 и в западном вентиляционном стволе шахты Панйи № 2 в угольном бассейне Панйи с водоносными наносами четвертичного периода толщиной от 200 до 400 м, состоящих из илопеска, мелкозернистого песка, среднезернистого песка, песчаного ила и бурлящего ила, применяется процесс искусственного замораживания и крепь из железобетона.

Вибрационные проволочные приборы, измеряющие деформацию, напряжение и температуру встроены в фальшивые рёбра для непосредственных измерений напряжения и деформации бетона.

В работе представлены некоторые результаты непосредственных измерений.