mgr inż. Justyna Sowińska-Botor Kraków, 22.05.2023 r.

PhD summary

ESTIMATION AND VERIFICATION PARAMETERS OF LOW VELOSITY LAYER USING STATISTICAL METHODS

The geological recognition of the low velocity layer (LVL), which is the highest part of the near-surface sediment section, is important for seismic research due to the fact that the accuracy of the calculated static corrections required for further seismic processing depends on the degree of knowledge of the seismic wave velocity within the LVL. Recognition of the velocity and thickness distribution of the LVL is complicated due to the large variations in the parameters of the seismic wave propagation and thickness observed there.

The research was carried out within Quaternary strata in the central-western part of Poland, about 30 km NNW from Poznań. Statistical analyzes of the given data were carried out by means of the STATISTICA 13.1 program, while calculations using geostatistical methods were carried out using the ISATIS 2015 software from Geovariances and the GEO-EAS 1.2.1 program. Isoline maps were calculated with the Surfer 11 program. Graphs and sections were made with the GRAPHER 9 program. The typesetting was performed with the LaTeX program.

Distributions of thickness and velocity parameters in the LVL generally deviate significantly from the normal (Gaussian) distribution, therefore it is necessary to select the methods that give the most optimal results in the conditions of strongly skewed distributions. The suitability of several geostatistical procedures for interpolation of highly skewed seismic data was tested. They were a combination of various estimators of the model of spatial variation (theoretical variogram) and kriging techniques, together with the initial transformation of data to normal distribution or its absence. Such transformation consisted of logarithmization or normalization using the anamorphosis technique. Two variations of the theoretical variogram estimator were used: the commonly used classical Matheron estimator and the inverse covariance estimator (InvCov).

The estimation of the values of the analyzed LVL parameters outside the measurement locations was performed using the ordinary kriging, logarithmic kriging and data integration kriging methods, which are effective and recognized methods of interpolation.

As a result of the conducted work, it was found that the estimation of LVL parameters in the conditions of difficult data distributions significantly deviating from normality

is possible, but requires the use of an appropriate calculation method. The research showed that in the case of data with non-Gaussian distributions, the most suitable variogram for modeling is the use of the Inverted Covariance estimator both on raw data and after normalization. An exception is the data after the logarithmization process, for which the most appropriate variogram for modeling was obtained with the classical Matheron estimator.

In the course of the research, it was shown that one should be careful when interpreting interpolation errors based on the kriging standard deviations calculated during kriging, which are too pessimistic, very often overestimating the actual errors by as much as 50-100%.

In order to improve the prediction of the LVL thickness, data from the uphole survey were supplemented with hydrogeological data on the depth of the groundwater table, which is comparable and often identical with the thickness of the zone of aeration determined during hydrogeological studies. This makes it possible to use both types of data in LVL studies. By using kriging with the integration of hydrogeological data, a significant reduction in the median of actual errors was achieved from 25% for the best model selected in the validation process to 5% for collocation co-kriging.

It has been shown that it is possible to reduce investment costs related to sampling the research area by means of significant decreasing the number of measurement boreholes necessary for reliable estimation. As a result of the research, it was found that the decrease of the distribution of measurement points to 2000 m, which was associated with limiting the number of wells to 61 out of 172 available, did not significantly influence the level of errors. The median of the actual error for the tested parameters increased (decreased in the case of V1) by only 1-2%. The distance of about 2000 m was assumed to be the most favorable for obtaining the best cognitive and economic effect. The presented results prove that properly selected geostatistical models can successfully replace a dense grid of measurements.