English-Language Summary of the Last Safety Audit of the Failed Dam at the Córrego Feijão Mine

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OVERVIEW

On August 20, 2018, TUV-SUD submitted a 126-page safety audit of Dam I of the Córrego Feijão Mine to Vale, the owners of the mine. The dam underwent catastrophic failure on January 25, 2019. The full document is entitled "Auditoria Tecnica de Segurança 2° Ciclo 2018—Complexo Paraopeba - Mina Córrego Feijão—Barragem I" [Technical Safety Audit 2nd Cycle 2018— Paraopeba Complex - Córrego Feijão Mine—Dam I] and is available only in Portuguese as a scanned image.

DESIGN AND HISTORY

There is no internal drainage in either the starter dike or the first dike above the starter dike. There are surface drainage channels that convey water from the dam crest down the downstream embankment of the dam. These surface drainage channels were designed to accommodate only a 25-year flood. There is also a system to convey the overflow of water from Dam I to Dam VI.

There was no study of the foundation prior to building the dam. For some dikes, it is not known whether they have internal drainages, as no records were kept. In many cases, it is not known whether designs were actually implemented.

PHYSICAL INSPECTION

Erosion of the downstream embankment was evident due to the lack of repair of the surface channels. The muddy water in the channels indicated erosion of the dam and improper leveling of the channels. Some channels were broken due to trampling by cows.

The majority of the internal drainage tubes had been damaged by cows. Some drainage tubes were clogged by vegetation. In some cases, mud in the water and staining on the embankment indicated internal erosion of the dam. Most of the drains lacked siphons to prevent air entry. In some cases, there were siphons, but they had been installed upside down.

All of the above had been cited in previous safety audits and had still not been corrected. In addition, this time the exit tube that conveyed the overflow from Dam I to Dam VI was clogged with silt.

DATA INSPECTION

The piezometric and flowmeter data were managed by GEOTEC. There were many inconsistencies in the data, for example, in some cases, the piezometric records indicated that the water was above the surface. Every attempt to correct the inconsistencies was unsuccessful. Many piezometric records were missing with no explanation. Some piezometer readings showed levels above the "attention level." However, these were difficult to evaluate due to the large number of inconsistencies in the data set. There was no instrumentation to evaluate stability above the water table.

It was impossible to reconcile the flowmeter measurements (monitoring the flow rates through the exits of the internal drains) carried out by GEOTEC with the measurements carried out by the dam operators. The two groups seem to have been using different coordinate systems to define their flowmeter locations. In addition, many flowmeter records were missing without explanation. The lack of correlation between the precipitation and flowmeter data also cast doubt on the validity of the flowmeter data.

The inclinometer data were completely worthless. In some cases, inclinometer measurements were recorded without specifying which inclinometer they applied to. There were large, unexplained datum shifts in the inclinometer data. Finally, none of the inclinometers had been installed correctly.

STABILITY ANALYSIS

The challenge in carrying out the stability analysis is that it depends upon the piezometric data, which is unreliable. In addition, due to the lack of seismological analysis and study of the foundation, there was no information as to what could be the trigger for liquefaction.

The undrained stability analysis indicated a factor of safety of 1.09. The critical slip surface showed global behavior, meaning that the slip surface went from the top of the dam to just above the foundation, so that the entire dam would fail simultaneously during liquefaction.

RECOMMENDATIONS

TUV-SUD recommended correction of all of the above shortcomings in dam maintenance and data collection. In addition, they recommended more efficient conveyance of water (using troughs and pumps) from Dam I into the overflow system. Finally, they recommended the installation of micro-seismometers and a study of the foundation downstream from the dam in order to better understand the potential triggers for liquefaction.

DID TUV-SUD SAY THAT THE DAM WAS "SAFE?"

Various news articles have been saying that TUV-SUD certified the dam as "safe." This is the strongest statement that TUV-SUD said that could have suggested that the dam is safe: "Notaram que por vezes o método de Spencer forneceu FS maiores e menores que o exato. Os resultados mostrados por aqueles autores indicam que um fator de segurança superior a 1,05 cobre um

possível erro envolvido no método de cálculo utilizado. Conclui-se que a Barragem I se encontra estável quanto à liquefação do rejeito, no cenário de instabilização sob a condição não-drenada, com FS > 1,05 ao serem considerados valores médios para a razão de resistência não-drenada do rejeito saturado." My English translation is: "They noted that sometimes Spencer's method [for calculating factor of safety] provided FS [factor of safety] larger and smaller than the exact one. The results shown by those authors indicate that a factor of safety higher than 1.05 covers a possible error involved in the calculation method used. It is concluded that Dam I is stable in relation to the liquefaction of the tailings, in the scenario of instability under the undrained condition, with FS > 1.05 when considering average values for the undrained resistance ratio of the saturated tailings."

This is my interpretation of the above statement: TUV-SUD said that the dam was stable, meaning the factor of safety was greater than one, *within the error of their method of calculation*. But the real error is the lack of complete and exact knowledge of the physical properties of the mine tailings. For that reason, the Dam Safety Guidelines of the Canadian Dam Association recommend a factor of safety of at least 1.5. Civil engineering structures are not supposed to be built or maintained at a point just slightly safer than the point of failure. In summary, TUV-SUD did not claim that the dam met generally-recognized dam safety guidelines. They just said that they were certain that the factor of safety was greater than one.