Mine Water and the Environment (2004) 23: 91–95 © IMWA Springer-Verlag 2004

Technical Communication

A Tragic Disaster Caused by the Failure of Tailings Dams Leads to the Formation of the Stava 1985 Foundation

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Abstract. This paper summarizes the dynamics and causes of the Stava disaster, and highlights some risky design procedures that led to the 19 July 1985 tailings dam failure. It then presents the "Stava 1985 Foundation", which was formed to focus attention on such risks and to strengthen the culture of respect for human lives and safety.

Key Words: Dam failure; Italy; Stava disaster; tailings liquefaction

Introduction

On 9 October 1963, about 300 million m^3 of rock detached itself from the left shore of the artificial Lake Vaiont, in northern Italy, and slid into the lake, creating a gigantic wave which struck the opposite shore, submerging it for over 200 m above the initial water level. The wave then swept back into the lake, onto the landslide and towards the dam. The dam resisted the impact of the wave but was overswept by it, so that a mass of 25 million m^3 of water precipitated from the dam top and erupted into a narrow passage and the Piave valley, felling trees and buildings and causing over 1700 deaths (Sammarco 1993).

On 19 July 1985, 67 km west of the above-mentioned Vaiont Lake, a tailings dam of the Prestavel fluorite mine, near Tesero (Trento), Northern Italy, failed, causing a disastrous mudflow involving 180,000 m^3 of semi-fluid tailings, which completely destroyed the hamlet of Stava and most of the buildings standing along the stream in Tesero. In this catastrophe, 268 lives were lost (Chandler et al. 1995).

The two destructive events were exceptional with respect to the dimensions of the masses involved, the amount of energy released, the rapidity with which events transpired, the damage that occurred, and the number of lives that were lost. The fact that the second event happened in the same general area as the first, and close enough in time that the first disaster should still have been fresh in everyone's memory might lead one to think that the second disaster occurred despite a higher level of precaution undertaken during design and construction. However, it appears that no higher level of precaution was taken and that any lessons learned from the Vaiont disaster had already been forgotten. Therefore, the "Fondazione Stava 1985" was formed to publicise the events and dynamics concerning the Stava disaster with the goal of preventing future catastrophes. A brief summary of the disaster, largely based on Lucchi (1995) and Tosatti (2003), follows.

The Stava Valley Disaster

The Prestavel mine tailings ponds were located approximately 120 m higher and 800 m away from the village of Stava, in a small valley lateral to the Stava river valley, and were mostly out of sight from the populated area. Two basins were constructed on boggy and weakly resistant glacio-fluvial deposits lying on dolomitic rocks (Rossi 1973), on an area inclined between 12° and 16°. The area also received runoff water from a 0.12 km^2 hydrographical basin inflows and from springs coming from other basins (Chandler and Tosatti 1995). The dam of the lower basin was erected on a porous starter dam anchored at the foundation soil, using the "upstream" method, which is the least reliable method with respect to stability. The dam of the upper basin was constructed without prearranging either drainage systems or anchorages, using the "centerline" method, so that as the dam grew higher, its base rested partly on the lower basin tailings (Campanella et al. 1989), and after that, by the "upstream" method. In 1985, the year of the disaster, the difference in altitude between the top of the upper dam and the base of the lower dam was about 50 m. The area occupied by the two basins and the volume of the stored material were, respectively, 30,000 m^2 and 300,000 m^3, which included 15,000−20,000 m^3 of free water. The downstream slopes of the lower basin dam and of the upper basin dam varied, respectively, between 26° and 34° and between 32° and 40° (Figure 1).

During the six months before the disaster, which occurred after the rainy season, rainfall had been slightly above average. On January 1985, a small landslide, and subsequently a sinkhole up-slope of the slide occurred on the right side of the upper dam, in the area where a decant pipe passed under the dam. They were attributed to leakages from this pipe due to its

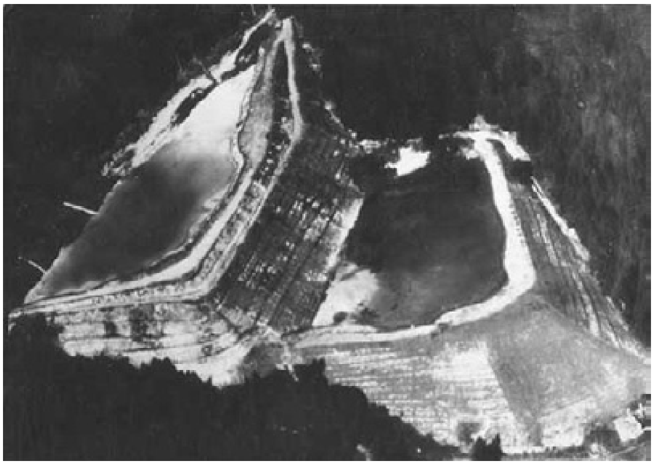

Figure 1. The tailings ponds of the Prestavel mine before the collapse (from www.stava1985.it)

blockage by freezing. Nothing was done to restore the pipe and the dam and, from January to March 1985, water seepages from the zone of the slide were noted. In June 1985, a sink hole 30 m wide and 3-4 m deep occurred on the left side of the lower basin, due to inflows of free water and tailings into the decant pipe lying on the bottom of the lower basin, as a consequence of its breakage. This material escaped through the broken pipe towards the Rio Stava. The ponds were partially emptied and the broken pipe was sealed with concrete and replaced with a bypass pipe that was placed on the down-slope of the lower basin dam. On 15 July, four days before the failure, tailings were again being pumped into the upper pond, where the dam was being raised to a height of about 30 m. The decant water was being discharged into the lower pond and then into the bypass pipe (Berti et al. 1988; Chandler and Tosatti 1995).

Nobody observed the sequence of the collapse, but reconstructions indicate that the first failure occurred in the terminal part of the right side of the upper dam. This failure would have triggered a large outflow of upper basins tailings, the collapse of the central part of the same dam, the sweep of the tailings over the lower basin dam and its failure. The resulting mudflow rapidly flowed downstream along the Stava Creek Valley, sweeping away or burying everything that was in its way. Seismographic data showed that the collapse of the tailings ponds and the quick outflow of the mud occurred between 12:22’55” (’= minutes, ”= seconds) and 12:23’55”; at 12:25’35”, a wave front higher than 10 m would have reached a velocity greater than 10 m/s at the village of Stava, which was destroyed and buried in 13 seconds. A mud wave with 1/10 the height and half the velocity would still have caused the collapse of reinforced concrete pillars (Sammarco 1999). The mud flow, after having rapidly passed through Stava, accelerated downstream, reaching velocities exceeding 25 m/s. When it swept away the Tesero houses that stood along the Stava River, the velocity was about 11m/s. The phenomenon began to attenuate itself at 12:31’00”, probably after most of the mudflow had reached the valley of the Avisio River, into which the Stava River inflows. This mudflow descended 480 m, and covered the 4.2 km distance between the basins and the Avisio River in 425 s, at a mean velocity of 9.9 m/s (Dellagiacoma 1990; Takahashi 1991). During its abrupt descent, the mudflow eroded soil, destroyed buildings and structures and uprooted trees, removing 40,000-50,000 m^3 of material from an area of about 27,000 m^2. Besides this material, the mudflow involved 5,000-10,000 m^3 of Stava River water which, together with the free water superincumbent on the tailings and the water contained inside the saturated tailings, contributed to the fluidity of the flow and therefore, its destructive power and its capacity for infiltrating into voids among collapsed structures (Figure 2). Otherwise, it is possible that such voids could have protected some life. But, if the filling of such voids would have been the last destructive effect of the mudflow, the first effect was a powerful impact air wave produced by the quick descent of the fluid mass. This pressure wave preceded the mudflow and formed a white cloud containing water, fine sand, and slime (Figure 3), which caused the destruction of trees and buildings before they were swept away by the mudflow. In particular, witnesses saw trees from a thirty year old wood, adjacent to the basins and located at the same elevation of the lower basin bottom, being uprooted or cut down by the pressure wave, even before the slide reached them (Figure 4).

Factors that likely contributed to the tailings liquefaction and dam failures include:

- The high amount of water in the tailings ponds:
  - In addition to water that separated from or were retained by the decanting tailings, water flowed into the ponds systematically (for there were no systems to intercept rainfall, effectively divert inflow from the surrounding slopes, or to intercept groundwater) and, unintentionally, from pipes lying in or under the tailings, due to problems that occurred soon before the collapse;
  - precipitation preceding the failure had been slightly above average, intensifying water inflow into the basins (Colombo and Colleselli 2003);
  - the drainage system was inadequate; this was especially true for the upper basin dam.
- Very low stability of the upper basin dam, due to: poor design (Genevois and Tecca 1993), excessive height; a very steep downstream slope, the manner of construction, the fact that part of the dam lay on the very compressible tailings of the lower basin (Chandler and Tosatti 1995), and the high piezometric surface within the dam and the high water level in the pond.

Figure 2. The Stava Valley after the mudflow (from www.stava1985.it)

- The unconsolidated state of the tailings and the relatively high slope of the natural ground under the tailings contributed to the thrust on the dam.
- The vibrations and running overloads due to the transit of some vehicles (Govi and Luino 2003) and an excavator on the dam crest might have caused liquefaction of material, which along with the increase in the crest height and the immission of tailings fluid, may have contributed to the triggering actions.
- The lack of water pressure controls or a monitoring system in and around the basin, and above all, in its dam (Sammarco et al. 2003).
- Possible warning signals, such as small slides and water seepages were either ignored or not recognized as significant.

It is impossible to be certain about what primed the failure, the exact sequence of events, their mechanics and their interactions, but based on the situation summarised above, it is clear that the basins would have collapsed, sooner or later. The high quantity and fluidity of the material contained in the basins, their considerable height, the relatively steep slope of the valley downstream from the basins, and the presence of inhabited areas in this same valley all indicate that the collapse would have had the same catastrophic consequences whenever it occurred.

The Stava 1985 Foundation and its Aims

While the geomorphologic, hydrogeological, static, and anthropic factors may explain the mechanics of the failure and the consequent catastrophe, they do not explain why a situation that was foreseeable and inevitable was not foreseen and avoided. There is no indication that consideration was given to assessing and avoiding the risk of failure during the design, construction, and management of the project. Given the location of the populated areas downstream and the nature of the terrain, one would think that some thought should have been given to not constructing tailings ponds in such a location, or at least to construct them in such a manner as to minimize the risk of failure, and to undertake actions that might have prevented or at least minimised the violent impact on the villages below. Apparently, no one was conscious of the enormous impending dangers; if they had been, monitoring and control systems could have been installed; at the least, there should have been some warning to allow possible evacuation from the threatened areas. To insure that the 268 innocent people killed on 19th July 1985 in the Stava Valley did not die in vain, the relatives of the victims established the "Fondazione Stava 1985" with the duty of keeping alive "the historical memory of the Stava Valley and Vaiont catastrophes and strengthening the culture of prevention, correct territorial management and safety since their shortcoming was the cause of these and other man-induced disasters" (Lucchi 2003). Such memory was defined by the President of the Italian Republic, Mr Carlo Azeglio Ciampi, as "not an end in itself but should be considered in an active sense, in order to awaken the accountability of each of us: because disasters like this one–the tragedy that Stava experienced and many others–depend essentially on the superficiality of those who have responsibilities" (Lucchi 2003). So, the memory of the Stava disaster, which given the number of victims, was the worst world catastrophe caused by the failure of tailings ponds dams, will permanently lead practioners and regulators to question oneself, to reflect, and to act. It leads us to ask why the Stava disaster happened, given that similar disasters had previously occurred. Had the news of these disasters not been sufficiently reported on, or their disastrous consequences not been properly emphasized? To increase awareness, the Stava 1985 Foundation organized an Information Centre, whose inauguration

Figure 3. A destructive impact air wave preceded the mudflow: a whitish cloud with fine sand and slime, raised by the pressure wave, stormed through Tesero (from www.stava1985.it)

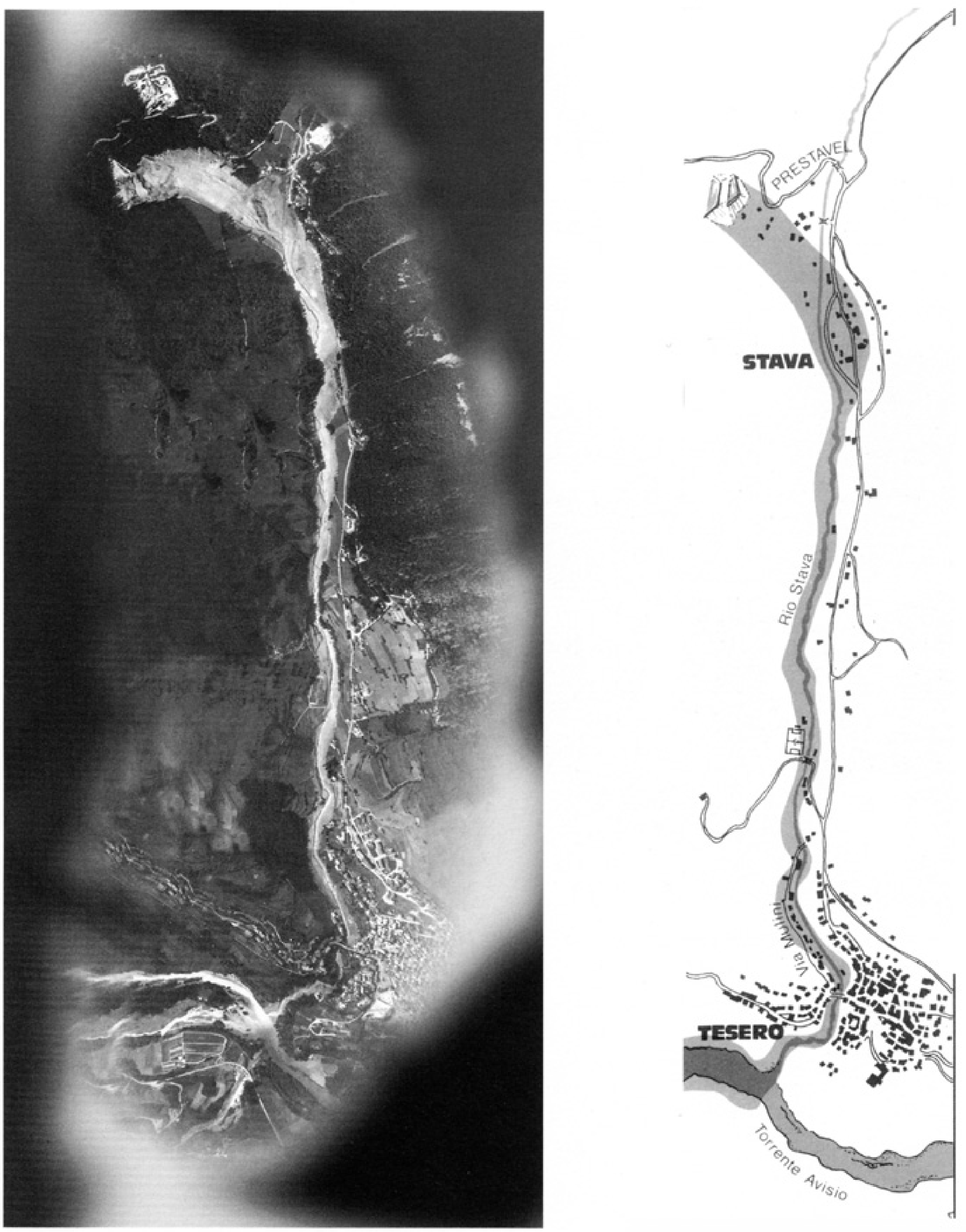

Figure 4. Aerial view, on the left, and graphic reconstruction, on the right, of the area impacted by the mudflow (courtesy of D.O.C. Doriguzzi)

the writer attended at Tesero on 22 November 2003 (Figure 5). At that occasion, the Stava disaster, with all its more significant details, was revived 18 years after it happened in a stimulating and involving way. The drama of the Stava and Tesero communities is now not just a remembrance doomed to attenuate, but a means to awaken accountability, leading individuals to select solutions that will guarantee tranquil sceneries in situations that may be very different from the Stava one. The fact is that after the Stava event, tailing dams have continued to fail and the mud had continued to flow in a catastrophic way many times and in many parts of the world. Perhaps the information has not yet been presented in such a way as to rouse sufficient understanding about the weakness of these structures and the need to prohibit their presence upstream from areas that are or could in the future be inhabited. The Stava 1985 Foundation

Figure 5. The Information Centre of the Foundation Stava 1985 and, in the background, the area where the Prestavel mine tailings ponds had been located

is aware of this, and intends to become increasingly involved in actions to avoid such tragedies in the future.

The Stava 1985 Foundation is currently led by Dr. Graziano Lucchi, who lost both his parents in the Stava disaster; it is a non-profit organisation with a social utility, and was established on 7th February 2002, with the high patronage of the President of the Italian Republic. The seat of the Foundation is in Tesero (Trento Province, Italy). Its web site, www.stava1985.it, can be consulted in English, German, and Italian.

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Submitted April 3, 2004; accepted April 25, 2004.