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3D Landsat-7 Satellite Image of the Pearl River Delta, China

This image was created from data collected by Landsat-7 on 2004-02-14 and 2003-11-03.



The Earth From Afar: Image Review

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Post Tsunami Reconstruction: The Semen Andalas Cement Plant in Aceh, Indonesia

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On December 26, 2004, a large and devastating tsunami hit Southeast Asia, tragically killing hundreds of thousands of people and seriously impacting the lives of well over a million more people. By far, the greatest number of deaths and amount of destruction took place in the Special Territory of Aceh, located at the northern end of the island of Sumatra, Indonesia. Aceh endured nearly 70 percent of the total number of deaths due to the tsunami. Of the nearly 4 million people living in the territory, an estimated 164,000 perished, tens of thousands were injured, and 300,000 now reside in temporary shelters (McBeth, 2005). Entire villages were eliminated and large sections of the population centers of Banda Aceh and Meulaboh were devastated. Large sections of Aceh need to be rebuilt.

The megathrust earthquake (9.3 magnitude, Richter scale) and the subsequent 1200 km (750 miles) long and 15 m (50 ft) uplifted fault, that generated the huge tsunami, occurred only a short distance (250 km or 155 miles) off the west coast of Aceh. With no warning three successive, gigantic waves, soaring up to 27 m (90 feet) high, hit this coast within twenty minutes of the earthquake. The authors recently published an article on the west coast community of Lhoknga, Aceh, which was reduced to one standing building (Baumann and Nellis, 2005). Even the boundaries of the surrounding rice fields were no longer detectable.

The recent report, *Indonesia: Preliminary Damage and*

Loss Assessment (2005), by Indonesia's national planning agency, Bappenas, identifies the major losses from the tsunami. Included in the list of key losses is the Semen Andalas Indonesia cement plant, which is located only two kilometers south of Lhoknga (Map). Cement is a major building block for any reconstruction endeavor and this plant is vital to the rebuilding of Aceh. With the use of satellite imagery and ground pictures taken by the United States Geological Survey and others, this paper examines the destruction of this cement plant and related facilities, and the importance of this plant in the reconstruction of Aceh.

Plant Destruction

Figure 1 is a Space Imaging's IKONOS satellite image taken on January 10, 2003, almost one year before the tsunami. The image shows the Semen Andalas cement plant, its dock facilities, and the limestone quarry immediately behind the plant. Frequently in developing regions, a company provides employees housing near a plant. In this case the plant's housing complex of 35 buildings lies 0.5 km from the plant on the seashore. This complex was the home for 100 employees and family members (Portland Cement Association). Based on the beautiful beach area and the lush tropical vegetation shown in the image, people living in this complex had a comfortable life style.



Map Special Territory of Aceh, Indonesia

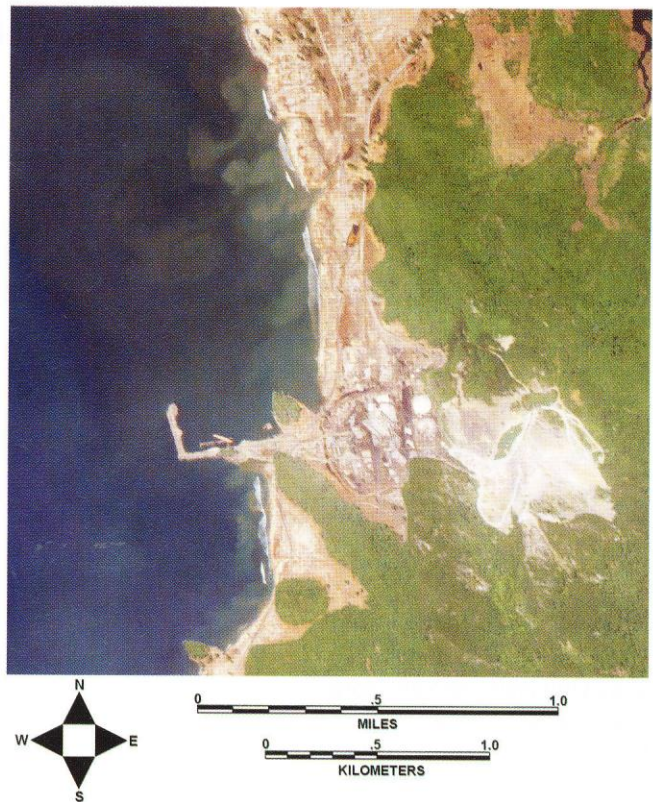


Figure 2 This image was taken by Space Imaging's IKONOS satellite on Dec. 29, 2004. Image acquired and processed by the Centre for Remote Sensing, Sensing and Processing (CRISP), National University of Singapore. IKONOS Image © CRISP 2004.

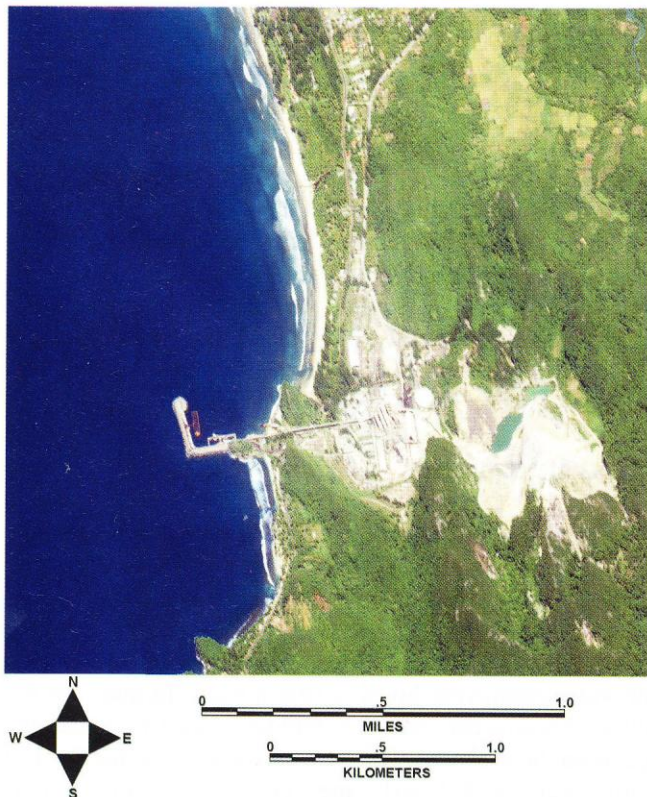


Figure 1 This image was taken by Space Imaging's IKONOS satellite on Jan. 10, 2003. Image acquired and processed by the Centre for Remote Sensing, Sensing and Processing (CRISP), National University of Singapore. IKONOS Image © CRISP 2004.

Figure 2 was also taken by Space Imaging's IKONOS satellite but on December 29, 2004, three days after the tsunami. The light brown color shown in this image represents the area decimated by the tsunami. With the exception of a few trees all vegetation was removed and only bare soil remains. Not one of the 35 houses survived. Figure 3 provides a ground view looking down toward the cement plant. The beach is gone and the area that was directly behind it is completely devastated. The tsunami waves that cut across this area were around 15 m (49 ft) to 25 m (82 ft) in height. The only evidence of human existence here are some building platforms, two non-functional roads, and a large barge with an accompanying tugboat. Figure 4 shows the barge and tugboat, which were washed ashore by the tsunami. They also can be detected in Figure 2. The barge still contains 400 tons of coal that was being delivered to the cement plant. As the waves came across the beach zone, they ran up the lower slopes of the hillsides. The maximum run-up of 34.5 m (113 ft) occurred on the hillside behind the barge (Figure 2), illustrating the power of the waves that forced the barge on the beach.

Figure 2 also shows a feature situated at a slight angle to the dock. This feature is a 6,693 dwt cement carrier "Sinar Andalas" that was capsized (Figure 5). Of the 19 crew members, only four survived. This ship contained cement that has now become concrete at the capsized site, making it a major barrier in clearing and rebuilding the dock. It was



Figure 3 View from Lhoknga, Aceh, looking down the devastated beach toward the Semen Andalas cement plant. Picture taken by the United States Geological Survey.



Figure 4 Tugboat and barge washed ashore by the tsunami. Picture taken by the United States Geological Survey.



Figure 5 Capsized ship at the Semen Andalas cement plant's dock. Picture taken by the United States Geological Survey.

used to transport cement to Belawan, Lhokseumawe and Batam Island for packing. The cement plant also encountered significant damage (Figure 6). Of the 625 people working at the plant, 262 are still missing. Initial estimates indicate that it will take nearly 100 million US dollars to put the plant and dock back into operation (Risk Management Solutions). A comparison of Figures 1 and 2 shows how the coastline has been eroded back to the perimeter of the plant.

Making Cement

Limestone, the primary raw material in the production of cement, is initially extracted from a quarry by blasting. Next it is crushed and transported to the plant, where it is stored and homogenized. To minimize the high transportation cost of moving crushed limestone, close proximity between the quarry and the plant becomes a crucial factor in the location of cement plants, which is the case with the Semen Andalas plant. Once at the plant the crushed limestone is ground into a very fine powder known as raw meal.

The raw meal is pre-heated using coal and placed in a kiln. Temperatures reaching 2000°C (3632°F) heat the raw meal to 1500°C (2732°F), and then the material is drastically cooled by air blasting. This heating and cooling process creates cement clinkers, the basic element in the production



Figure 6 Damaged cement plant. Picture taken by the United States Geological Survey.

of all cement. The high temperatures associated with the heating process result in high energy costs, almost 50 percent of the operating costs. Clinkers in combination with a small amount (5-10%) of gypsum (improves the setting time for the concrete mix) are mixed together to create "pure cement". Secondary constituents are also added to make blended

cements. Finally, the finished product is stored in a large silo waiting to be transported in bulk or in bags to the market.

Plant Location

The Semen Andalas Indonesia plant was built in 1983 with financial support from the International Monetary Fund. Initially it was a government owned operation but in 1994, Lafarge acquired it. Lafarge, a French based company, is a world leader in cement production, covering 75 countries and employing 77,000 people. The plant controls 80 to 90 percent of Aceh's cement market (Guerin, 2005).

Limestone, previously identified as the main component in making cement, is abundant in many regions of the World. This condition allows cement generally to be produced at numerous local sites. Lafarge seeks out sites that possess large quantities of high quality limestone. It wants a plant to have limestone reserves for at least 50 years. To build or acquire a plant requires a huge capital investment that will take several decades to reach a break-even point. A cement plant is a specialized facility that cannot be converted to other uses; thus, the fixed costs of building or acquiring a plant are quite high, often representing more than 50 percent of the overall production costs. With respect to variable costs, automation has decreased labor costs; however, energy costs continue to be a significant operating factor.

With high quality limestone being readily available throughout the World, location costs become the important factor in determining where to have a cement plant. A good location is near (1) a large market, (2) easily accessible limestone, (3) available, low priced energy, and (4) a low cost transportation system such as a railway line or more preferably a water network. An inland plant using trucks rarely transports bulky cement more than 200 km (125 miles). The Semen Andalas plant is situated only 25 km (16 miles) from Banda Aceh, the territorial capital and a market of approximately 200,000 people. The cement can be transported to this market by land or water. Sumatra has over 44,000,000 people, a considerably larger market but due to the island's mountainous topography land transportation is not economically feasible. Water transportation must be used, thus, the plant's dock facility as shown in Figure 1. The island's mountains are karst in nature, and karst topography is based on limestone. Immediately behind the plant is a quarry with large amounts of high quality limestone. Consequently, the plant has easy access to limestone. Cement production requires a considerable amount of energy. Thus, the Semen Andalas plant uses low priced coal rather than high priced oil. The coal barge beached by the tsunami reflects this situation. The use of coal also relates to the Indonesian policy of stressing the use of low priced natural gas and coal by domestic industry and households. This policy allows petroleum-based fuels used by the domestic market to be significantly reduced and make more oil available for export at higher revenues. The Semen Andalas plant possesses all of the location conditions required for a cement facility.

Rebuilding the Semen Andalas Plant

Before the tsunami occurred, the Semen Andalas plant was experiencing low profits and Lafarge had to evaluate the potential post tsunami market before committing to rebuild. On July 7, 2005, Lafarge announced that it would rebuild the damaged cement plant at a cost of US \$90 million. Risk Management Solutions, Inc. (RMS) (2005) reported that the Semen Andalas plant and the complex of 35 homes should receive about US \$100 million in natural disaster insurance; thus, most of the cost to rebuild should come from insurance compensation and not directly from Lafarge. The facility was heavily reinsured in both the Paris and London markets (Aloviai, 2005). The new plant will have state-of-the-art technology, which will make it more automated, and thereby, decrease labor and energy costs. The plant will resume operations in mid-2007 and will produce 1.6 million tons of cement annually.

In the short term a large floating terminal will be moored off the coast to bag bulk cement. Cement will be imported by Lafarge from its Malaysian subsidiary in order to handle the high demand for cement in the region. The Lafarge terminal will handle up to 1,600 tons of the cement daily until the plant is operational.

Trucking cement over difficult road conditions from ports some distances away is now occurring but this type of delivery system adds tremendously to the cost of cement at the market. The nearest plant is located at Padang (Province of West Sumatra). Cement from this plant is being transported by water to the port at Lhoksemauwe located on the east side of Sumatra. From Lhoksemauwe it is transported by land down the Asian Highway Route 25 to Banda Aceh, a distance of 275 km (171 miles). Due to the added transportation cost, the price of a bag of cement has gone from 20,000 rupiah (\$1.98) in Banda Aceh to 29,000 rupiah (\$2.87), a 31 percent increase. At Meulaboh, yet another 145 km (90 miles) away, the price is 33,000 rupiah (\$3.27). The Lafarge terminal arrangement should significantly reduce the transportation cost on cement in the Aceh region. Banda Aceh is only 25 km (16 miles) away from the terminal and Meulaboh is 120 km (75 miles). As previously stated, trucks are rarely used to transport bulky cement more than 200 km (125 miles).

Cement Demand

According to Refugees International (McNaughton and Thompson, 2005) over 100,000 houses and businesses need to be reconstructed for tsunami survivors, which will require large amounts of construction materials, especially lumber and cement. Lumber creates a particular problem since the government will not allow Aceh's timber rich forests to be logged. The illegal harvesting of tropical hardwood trees in neighboring Kalimantan has created many environmental problems and the government is concerned that these problems will expand into Aceh. Thus, more cement might be used in the construction process. The reconstruction of such a large number of houses and businesses and the

limitation on the use of local wood should produce a great demand for cement.

In addition to buildings, the transportation infrastructure needs to be replaced. The largest of these infrastructure projects is the 150-mile (240-kilometer) two-lane highway between Banda Aceh and Meulaboh that needs to be rebuilt. This road runs along the west side of the Special Territory of Aceh, connecting many small coastal communities shattered by the tsunami. At least 110 bridges were destroyed along this road and whole spans were carried hundreds of meters inland. An estimated 30 percent of the road has been destroyed. Also, large sections of the road were located on the flatlands between the sandy beaches and the rice paddies. In these sections the highway is basically gone. The rebuilding of this road might require moving it inland farther, along the edge of the rugged highlands and across good farmland, which is rather scarce especially since the tsunami. Through the U.S. Agency for International Development (McBeth, 2005), the United States will rebuild this vital road. This project, and many similar ones throughout Aceh, will create the need for huge amounts of cement. In addition, this road project is particularly critical for the Semen Andalas plant since it is located on this transportation system, which gives it access to Banda Aceh and Meulaboh.

Summary

As previously stated, cement forms the building block for reconstruction in the Special Territory of Aceh. Once reconstruction work gets started, demand for cement will soar. However, the Semen Andalas plant near Lhoknga needs to be put back into operation rather quickly. The Semen Padang plant is the nearest cement facility to the disaster area but it will not be able to keep pace with the expected demand and to deal with the very high transportation costs. The temporary arrangement of a floating terminal at the destroyed Semen Andalas port with cement being

imported from Malaysia represents Lafarge's attempt to continue its dominance in the Aceh market. Also, this arrangement will keep the price of cement high. The remotely sensed imagery and accompanying ground pictures presented in this paper illustrate the immense task of getting this vital building material, cement, into the hands of the people that need it in order to rebuild Aceh.

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