Geocells Keep Mexico City's New Airport from Sinking

Above: Partially infilled NPA geocell road construction over clay mud swamp. Inset: Heavy construction machinery sinking in airport's soft clay mud (no NPA geocell reinforcement). Photo credits: Innovater

The ancient Aztecs built Tenochtitlan, the city-fortress capital of their empire, in the middle of Lake Texcoco in the Valley of Mexico in 1325. This monumental city rose from a network of canals and artificial islands, replete with fertile gardens, gleaming towers, causeways to the mainland and aqueducts for fresh water. Two hundred years later, the Spanish conquered and razed the city, and then rebuilt their capital on top of the original urban grid of canals, city, and farmland. Renamed Mexico City, it became one of the most important and beautiful cities in the America's, referred to as the "Venice of the New World" and the "City of Palaces."

Creating a teeming metropolis on a former lake however, has significant impacts. Consolidation of the clay soil over the last 500 years resulted in a 30–60 m deep soft clay mud layer. This compressible soil is subject to continuous settlement, particularly when the underground aquifers are pumped for drinking water. Many structures in the city sink 7–10 cm per year.[1]

This is the challenge facing the planners of NAICM (New International Airport Mexico City), the new $9.5 billion (Phase I) airport at the city's eastern edge: How to build one of the world's most ambitious airports on unstable, saturated, and sinking soil? Conventional construction methods will either not work or are too expensive.

Project planners selected a three-dimensional, honeycomb-structured geocell made with Neoloy®, a Nano-Polymeric Alloy (NPA). The system, when filled with soil, provides high-strength reinforcement, high elastic stiffness, and excellent tensile strength and creep resistance.

A New Airport For Mexico City

The new Mexico City airport is designed to be one of the largest, most futuristic and most sustainable airports in the world. The project involves an international consortium of designers and engineers and no shortage of national pride. Covering 4500 hectares, Phase I will support 57 million passengers per year in 2020. Phase II will double that capacity.

The airport roads, railways and runway infrastructure faced the same difficult soil conditions that influenced the design for the terminal building. British architect Lord Norman Foster, leading one of the international design firms stated: “the soil has a high water content and has little capacity to support large loads. In addition, the area is seismic, and the effects of ground movement are magnified by the soil type in the area. Finally, the site is subject to substantial settlement over time, from groundwater extraction for the drinking water supply of the city.”

Traffic design requirements for the road projects were: 1200 passes of T3-S3 dump trucks (45-tons) per day. The upper layer of this soft soil is a very thin layer (20-25 cm) of clay with a 1% CBR (California Bearing Ratio). Under this is a 30-60 meter deep layer of clay mud with a 0.6% CBR. This consolidated mud layer makes road building extremely difficult, the soil is extremely soft, saturated and highly plastic with wet-dry cycles that cause extensive potholes and cracking of the surface.

Innovaciones en Terracerías, S.A. de C.V. (INNOVATER) proposed the geocell solution for the roads in consultation with ANCORA INGENIERÍA – experts in airport runway and platform pavements – and with Mexico’s leading infrastructure design and geotechnical engineering companies, already extensively involved in the airport.

In a 4-month comparison test of several different soil stabilization solutions conducted by the NAICM engineering authorities, the geocell from PRS proved to be a reliable solution for the site’s heavy truck traffic.

Finding The Reinforcement Solution

A conventional road design was unsuitable as the aggregate and asphalt layers would have to be unreasonably thick and costly, given the compressible soils.

Soil removal and replacement was deemed unfeasible due to the enormous quantities of earthmoving involved. Also, the high groundwater level complicated the safety of construction equipment, which would likely sink in these conditions during soil removal operations. Removal and replacement was also far too time-intensive for the project schedule.

Chemical soil stabilization methods were ruled out, due to application problems. Much as with soil removal, chemical soil stabilization would require heavy equipment that the site could not support in its pre-stabilized state. Furthermore, this method was ignored due to its lack of homogeneity, lengthy curing time, unreliable durability, environmental impact, and high cost.

Geosynthetic mechanical soil reinforcement was the best choice.

Various geosynthetic systems were evaluated. These included nonwoven geotextiles and two geogrid layers installed on a demo test with 45 cm layer of Tezontle volcanic rock infill. However, the system ruptured and potholes developed.

HDPE geocells were considered unstable for heavy-duty, long-term use, therefore NPA geocells were tested and selected. The NPA geocell testing involved four months of 45-ton truck traffic passing. The demonstration section showed no surface deformation or settlement.

Additional support for the NPA geocell material came from a similar project in the currently operating Mexico City Airport. There, conventional pavements in one of the airline platforms suffered an average of 18 cm consolidated settlements in the first year in the same saturated lakebed soils as the new airport. The installation of geocell stabilization reinforced the airport aprons and platforms. Four years later, and after regular measurements were taken and analyzed, authorities noted that settlement had not occurred.

NAICM authorities, reviewing this information and the test site data, selected these geocells for soil stabilization and ground improvement.

The readily available Tezontle volcanic rock infill was, on its own merits, only marginal quality, but the geocell could improve the modulus of this low strength (and ungraded) infill by a factor of 3.5. Thus, the pavement structure would be strengthened significantly while the lightweight infill reduced the overall pavement system weight. It was an optimal design.

NPA geocells can reduce asphalt layer by 20% and structural layers by 50%. Photo credit: Innovater

Construction Notes

Construction began in the spring of 2016 on 34 km of the first stage of the road network. Roughly 80% of that work is already in operation or about to open.

Installation of the 84-cm total pavement thickness is simple and straightforward. After clearing and grading the subgrade surface, a nonwoven geotextile and biaxial geogrid are installed on the subgrade-subbase layer interface.

The geogrid layer can be in part considered sacrificial. It acts as a stable working platform, which improves the performance of the geocell installed above it. This composite geosynthetic system design exceeds the sum of its separate parts to maximize the reinforcement factor.

Next, the geocell sections (PRS-Neoloy-330-120-C) are installed. After fastening the folded sections together, the sections are then opened and placed over stakes on both sides of the road. The geocells are then infilled with 12 cm of Tezontle rock infill (0.5” to 3”) with an additional 3 cm minimum overfill and compacted by standard road building procedures.

The remaining subbase layer is then infilled and compacted, followed by the base layer (high quality aggregate) infill operations. The asphalt concrete surface layer is then paved on top. Standard road construction quality control tests are used.

System Benefits

The new roads are performing as designed, with zero settlement, rutting, bumps or hollows forming. With the geocell-reinforced pavement system in place, the overall NACIM Phase I project is proceeding on-schedule with access roads, runways, parking lots, and the terminal building is progressing.

One of benefits to this geosynthetic approach is that specified geocells can be installed in all weather conditions. This has greatly sped up the construction process, particularly for this site which must weather a rainy season up to six months long. Despite the precipitation, the heavy equipment and the 45-ton dump trucks on unreinforced road surfaces have not sunk. Operations continue.

Additional benefits of the geocell design have been the time-related cost-savings to the project. For example, soil removal and replacement would have required more than a year longer than the utilization of these NPA geocells and lightweight infill.

Maintenance of the system has been significantly reduced with geosynthetic reinforcement. In addition to the previously noted modulus increase (3.5x), the time between maintenance cycles has been extended by 4x.

And, the ability to use locally available structural infill has lowered the environmental footprint of the project, by reducing quarrying, hauling, pollution, and the carbon footprint. With the ambitious sustainability goals for the site, this is precisely what NACIM’s planners wanted.

Construction on Mexico’s new international airport is achieving its early goals. As the case study here shows, the site is doing so through the engineering, environmental, and economic benefits provided by the selected materials and project partners. These smart decisions include the incorporation of NPA geocell technology. **L&W**

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[1] Mazari M. La isla de los perros. Mexico: El Colegio Nacional; 1996