

GEOTECHNICAL: SIKKIM AIRPORT



Tall order: Working in the steep slopes, mists and rains of the Himalayas

INDIAN SLOPE TRICKS

Extremely high reinforced earth embankments with near vertical facings are breaking records on the Sikkim airport project in India. **Adrian Greeman** reports.

In the mist-smoked mountain valleys of the Himalayas a series of giant stone walls is rising high on the steep slopes, reminiscent of ancient fortresses and Mughal emperors. High sheer curved ramparts are more like the fantastical images of Buddhist temples from a Hollywood movie.

Real Buddhist temples dot this area, the autonomous Indian state of Sikkim, close to Nepal, Bhutan, and the Chinese border. But these walls are for something much more 21st century. They are a major feature of a new airport, the first in the province and a crucial development for the inaccessible territory of plunging hillside, rice terraces and isolated towns and villages, connected by potholed contour-hugging roads and rickety truss bridges.

This inhospitable terrain has prevented full development of the state and particularly tourism, despite major attrac-

tions like the scenic mountains, rich natural history and temples. The International Centre for Orchids is headquartered here and a reputed 1,800 species of butterfly can be seen.

Strictly speaking the huge rising structures are not walls as such. They are gabion-basket facings for massive reinforced earth embankments, which help create a flat platform for the runway and the aircraft apron and terminal.

Above the gabions, the upper parts of the steep sided slopes are less steep and are faced with a vegetated mesh. Maccaferri is supplying the gabions and mesh and has worked closely on the design details with main consultant Mott MacDonald India.

Such a dramatic use of reinforced earth is not only unusual but probably unprecedented. Most such structures rise not more than perhaps 15m with a few examples in the world »

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» reaching 40m for the entire embankment.

But the necessities of the project demand something exceptional. The constraints are severe, explains Sharad Kumar, the scheme's general manager from client the Airports Authority of India.

They include steep slopes, mists and rains, nearby mountains on the flight path, strongly weathered ground conditions, and a major seismic risk. The area experienced a strong 6.8 Richter earthquake only this September.

The airport is sited on the side of one of the local mountains, which rise in this lower Himalayan area to around 2.2km, and for reasons of weather and wind gusting must be within a certain height envelope of between 1.35km and 1.5km.

The selected site, near the town of Pakyong and approximately 33km from the capital Gangtok, will allow for a north to south runway to be built along the mountainside which slopes at more than 50° from west to east in places. Because its 1.7km length will serve international AT72, 66 seat aircraft, the runway gradient has to be less than 0.7%.

Making space for the strip is difficult and made even more so by the need to completely minimise land take.

"Land is in short supply in these regions," says Kumar. Additionally, he adds, ecological and landtake reasons led the local state to rule that fill should neither be exported or imported.

All this meant that a completely balanced cut and fill design was needed within the tightest possible footprint, with land take kept at 56ha.

The only way to do that was by building high faced structures, says Mott MacDonald senior engineer Rahul Vaidya. Gentler batters would have extended the structures halfway down the fairly well populated valley sides.

The rear of the site will be cut back with cuts to 110m high, and embankments created lower down up to 74m high.

This work was a significant design challenge not least because the geology is a mixture of sedimentary or metamorphic rock, with some granites, schist, gneiss and all highly weathered to depth.

The final structure has to cope with seismic loads and one of



the world's highest rainfalls – a four month monsoon here is only part of the overall 2.5m annual precipitation. This year has already seen 3.9m of rain.

"And the peak intensity of

Constraints include steep slopes, mists and rains, nearby mountains on the flight path, strongly weathered ground conditions, and a major seismic risk

the rainfall is also very high," adds Kumar. Not only that but there are eleven local streams, called *jhoras*, nine of which pass through the runway area with all that implies for pore pressures and ground stability.

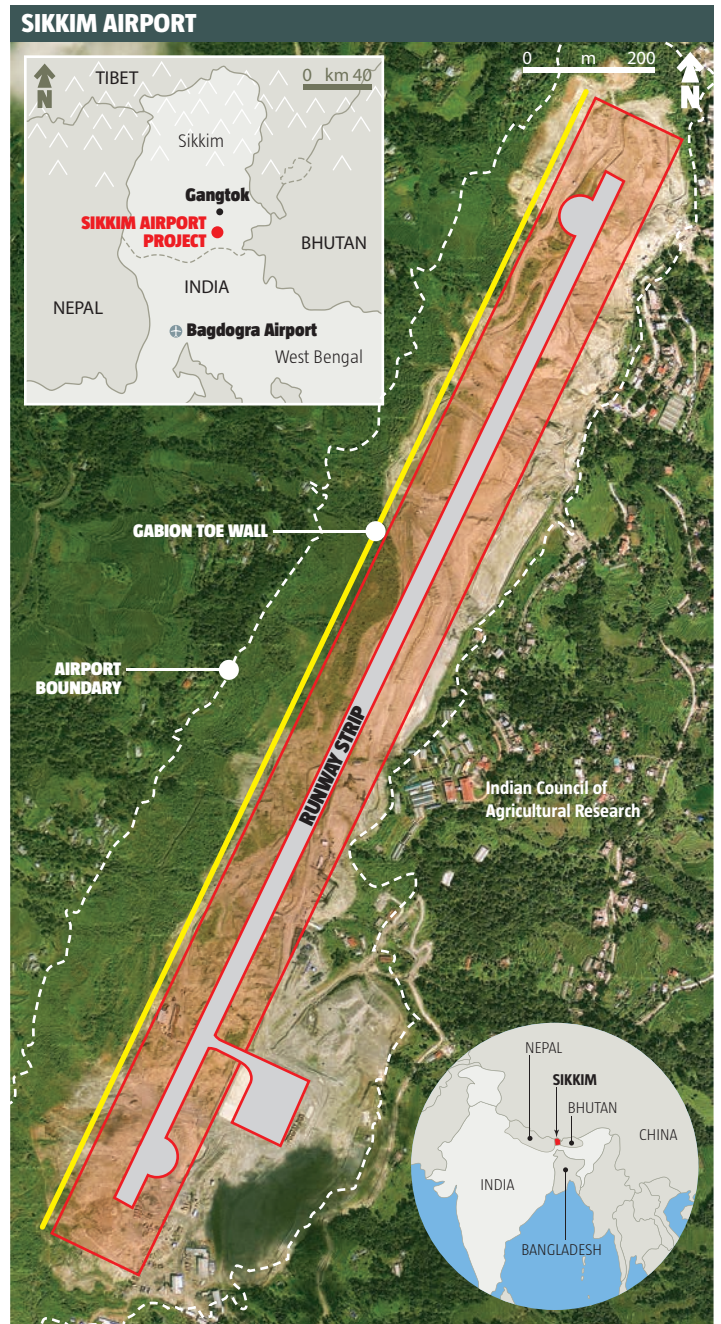
Rigid reinforced concrete retaining structures were looked at but ruled out, says Vaidya. They were unsuitable in the seismic conditions and obtaining sufficient concrete in the region would also have been problematic.

Instead, a more flexible design option of reinforced soil embankment was chosen to support the fill area. For the facing the options included systems with rigid concrete

panels; wraparound methods and welded mesh walls. In the end, gabions were selected for the steepest sections of wall and a wraparound mesh facing from Maccaferri called Terramesh for the less vertical sections.

"The flexible solution is good for effective drainage and earthquake resistance," says Ashish Gharpure, director of Maccaferri India.

Maccaferri's Paramesh geosynthetic grid was selected for the main earth reinforcement. It is a very strong grid and allows for a design with an unusual spacing of up to 2m between reinforcement layers in some places. This makes it quicker to install and more



economic. Most of the grid layers are 1.6m apart.

The grid's load bearing capacity of up to 800kN/m also allows for flexibility in the design, minimising costs, says Maccaferri. Main design was to BS 8006 for the static design of slopes and walls, and to the American Federal Highways Administration standards for seismic design not covered in the British standard.

The system is being used to form composite embankments, faced with large 1m deep gabion "blocks" in a near vertical configuration at the bottom and then with a gentler 65° vegetation stabilised slope above. The steep facings, at 6° from the

vertical are mostly in sections with intermediate step-backs, although at one point above a stream valley there is a sheer face 40m high, says Gharpure.

For the sloped facings

The system is being used to form composite embankments, faced with large 1m deep gabion "blocks" in a near vertical configuration

Terramesh is being used. This is a steel mesh reinforcement interleaved with the main grid reinforcement as a secondary reinforcement and then wrapped around at the face. Where space is available this is "Green Terramesh" which has coir, a coconut matting, included on the facing. Behind it goes some topsoil and seeding to generate vegetation cover.

Vegetated matting is the main stabiliser for the up to 11m high cuttings behind the runway, using coir blankets made from coconut matting and polypropylene netting, held down with U-pins like giant staples until plant growth is well established. The base of the cuttings is

stabilised with a gabion toe up to 3m high.

Kumar explains that the three most critical elements of the design have been "drainage, drainage and drainage".

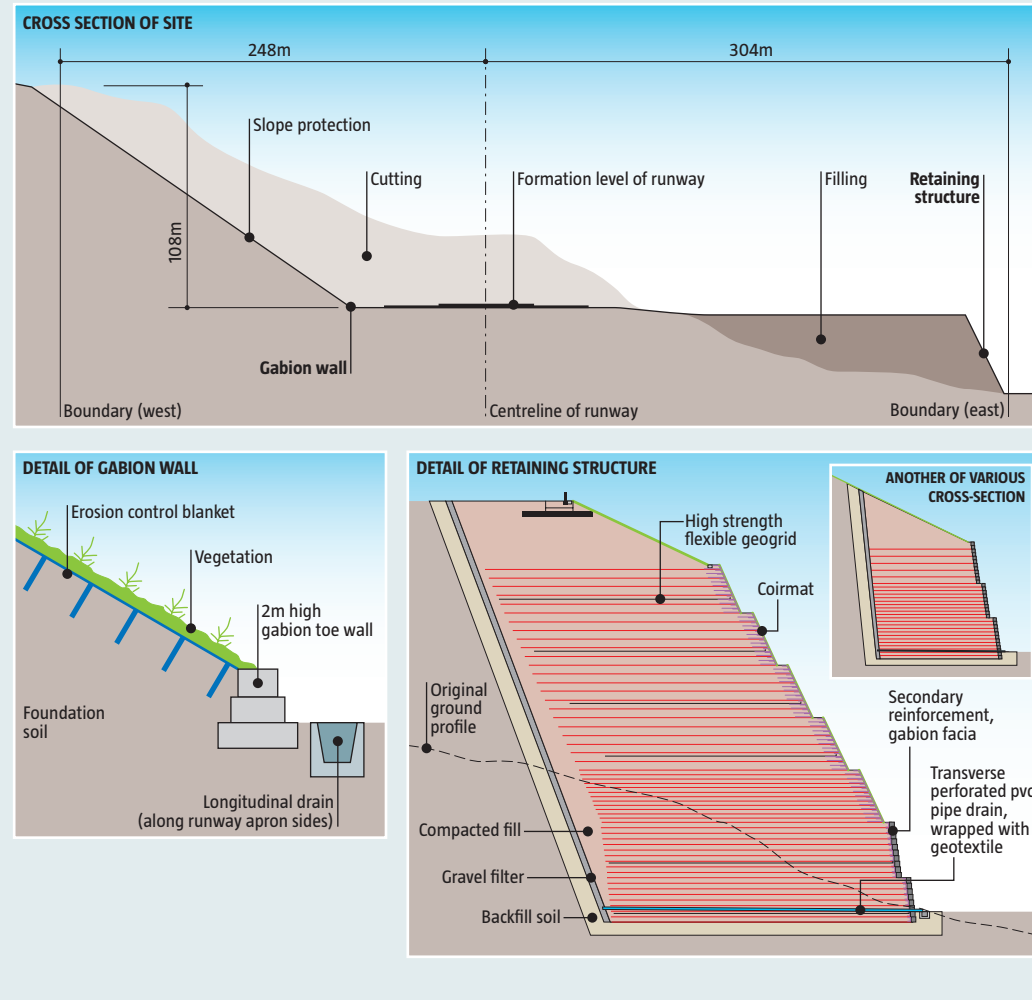
To cater for high rainfall, substantial catchwater capacity and slope drains are needed on the cuttings, with the flow collected by longitudinal drain channels next to the runway.

Even more important is keeping the embankments drained. To ensure this each fill area has parallel perforated pipes drains installed at 10m centres in the base.

"And then at the back of the reinforced section we have a special feature, the chimney >>

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BASIC SCHEME OF RETAINING STRUCTURES



» drain,” says Kumar. This is an essentially a dry-stone wall, 250mm wide and wrapped in Terram 1000 geotextile, to act as a filter and prevent clogging from the ingress of soil fines. The wall is built with 100mm to 250mm flat hand-shaped and hand placed stones. It rises the full height of the embankment.

On top of that however has been the need to deal with the *jhoras* running through the site. Mott MacDonald’s solution has been to draw the eleven streams together into four main routes through the site in large concrete box culverts. Concrete was selected over a steel option because of its stiffness, particularly in a seismic event.

The culverts which also collect the drainage from the slopes and runway, emerge in the faces of the near vertical gabion walls. Here stepped structures have been built up using gabions, to break the flow of the water and dissipate the energy in it, which can be significant in a full

monsoon storm.

Dealing with *jhoras* has been doubly important because of a significant population living further down the valley slopes. Widening work has been needed in downstream channels to accommodate the increased flow in the composite channels.

But the streams are also important as the main water source for the local population. Below one of the culverts a new reservoir has been designed, says

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Vaidya. From this, piped supply connections are being made.

If design has been complex, so too has the construction operation.

Firstly the remote area is not the easiest to work in. Bringing in the substantial amount of plant had its own difficulties. Around 76 excavators of which 18 are large machines, concrete paving machines, compactors, generators, a crushing plant and concrete mixers had to be transported to the site. Each had to come along the 80km of winding and sometimes worn or potholed roads that run from the plains.

For Delhi-based main contractor Punj Lloyd, that usually meant breaking machinery down into three or four pieces to get it across the bridges which usually are limited to around 7t to 8t maximum load.

On site work is limited by the heavy rainfall particularly during the spring and summer monsoon period. Finding skilled

labour is also a problem, especially to operate truck, excavators and other machinery.

The embankment work requires significant skill. A critical aspect is placing and properly compacting the fill which is done in 300mm layers. Moisture content has to be within the right range, so the material must be turned to dry it. A compaction density of 98% is required.

“Compaction is especially important with such embankment heights,” says Kumar. “And settlement could be significant if it occurred.”

The contractor has an onsite laboratory to carry out a range of soil testing.

Work is sequenced with much of the machine work to cutting and moving fill done under floodlights at night. Bulldozing the layers is done in the morning. An element of the fill work is the removal of boulders and stones from the placed fill material.

There is a substantial workforce used locally, working in 40 day cycles. “They are terrace farmers mostly and need to return home to work the fields,” says Kumar. Local workers are used for much of the gabion filling, and soil and seed placement for the Terramesh.

The hand filling of the gabions is part of achieving a very clean and neat appearance on the near vertical facings. “It is also important that the local stone is placed with the strike plane horizontal,” says Vaidya, “as the rock has good compressive strength that way but much less along the plane.”

So far this effort has taken the structure a bit beyond halfway. Progress has been slowed this year in particular by the exceptionally heavy rains and “some other factors”, says Kumar. The 6.8 earthquake in September has not affected the airport however, he says.

There is the concreting of the runway and apron area to come as well as construction of the terminal and control tower buildings. The main contract, for some Rupees 2,560M (£31M), was due to have taken two years from the start of work in January 2009 but will not be complete until well into next year. The work to complete the airport buildings will continue until December next year.