Sethusamudram ship channel macroproject: Anti-tsunami and storm surge textile arrestors protecting Palk Bay (India and Sri Lanka)

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During times of periodic storm and unpredictable tsunami causing public peril in Palk Bay, textile barrier (dam) technology can be employed to protect an economically important region between India and Sri Lanka. Anti-tsunami and storm surge arrestors are a new development applicable to Palk Bay, especially with the construction of the Sethusamudram Ship Channel.

Keywords: Adam's Bridge, India, Palk Bay, Sethusamudram Project, Sri Lanka.

BARELY 40 km separates India and Sri Lanka at the Palk Strait. Prior to the 24 December 1964 cyclone passing through the Palk Bay, the two countries had been connected by a train–ferryboat that traversed the strait between Dhanushkodi (India) and Talaimannar (Sri Lanka). A chain of limestone shoals, named 'Adam's Bridge', lies within the strait, almost affording a land connection between Mannar (Sri Lanka) and Rameswaram (India). Sri Lanka can be physically joined with India for energy generation[1] and transportation purposes[2].

Much of the shoreline of western Sri Lanka bordering Palk Bay is < 10 m above present-day sea level[3] and ~ 50% of Palk Bay is < 10 m deep. Navigable waters of < 10 m depth constitute shallow water, where surface waves are noticeably affected by seafloor topography. Its natural northern maritime approach is restricted by the presence of Pedro Bank, while its southern ship approach is almost blocked by Adam's Bridge, a string of low-elevation atolls. The Sumatra–Andaman earthquake (moment magnitude 9.3) on 26 December 2004 and its aftershock-like companion Nias earthquake (moment magnitude 8.7) were the largest in the region for over 40 years[4]. (Sri Lanka's west coast was struck shortly after low tide, while India's east coast was inundated shortly following high tide.) The Sumatra–Andaman seismic event generated a 30 m tsunami that disastrously, and tragically, impacted Sri Lanka and India on the same day. The propagated tsunami, moved westwards rapidly, encompassing the periphery of the island nation of Sri Lanka, with waves converging on Palk Bay from the two sea approaches to Palk Strait. In the districts of Jaffna, Kilinochchi and Puttalam, thousands of persons died when the tsunami swept ashore, destroying villages and damaging city waterfronts. When they returned to their means of making a living, the local fishermen from India and Sri Lanka subsequently discovered that nearby fishing grounds in Palk Bay and elsewhere had been drastically altered by tsunami-shifted seafloor sediments. Cathcart had warned strongly, during 2003, of the potential of dangerous future tsunamis entering Palk Strait, affecting any kind of natural or anthropogenic fixed physical feature in the Palk Strait linking India and Sri Lanka and, as well, noted the marked impact of the infamous 24 December 1964 cyclone that traced (from east to west) the route of Adam's Bridge, pummelling Palk Bay's surface and mainland with winds of up to 270 kph and generating within the Palk Bay an estimated storm surge of ~ 6 m near Pamban.

There are a number of reported instances where deliberate alterations, such as commercial and residential beach alterations, of the India–Sri Lanka coast modified the run-up behaviour of the 26 December 2004 tsunami. The unwise destruction of mangroves on land[5], and long-term offshore coral mining, allowed greater tsunami penetration than would otherwise have probably taken place[6]. Post-tsunami recovery and assistance assessments by geologic and geomorphologic experts produced some surprises. For example, India's Buckingham Canal (also known as National Waterway #4), which was completed in 1878, shielded many people there from a significant part of the tsunami's onslaught[7]; on its sunken barrier–storm water drain tsunami run-up wave macro-engineering model, the seashore-paralleling Ananda Victoria Marthandam Canal (National Waterway # 3), first made operational in 1860, may also have important additional 21st century uses not previously contemplated by its 19th century planners! Canals such as the Mississippi River Gulf Outlet-Industrial Canal that penetrate land perpendicular to the coast can have dire consequences, as was observed during the storm and tidal surge events accompanying hurricane Katrina of 29 August 2005 at New Orleans, USA.

Ravilious[8] disclosed the gist of Schuiling's macro-engineering concept for raising the level of the Adam's

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Bridge atolls by creating an artificial stone (gypsum) by geochemical conversion of a natural stone, the atoll-underlying Jaffna Limestone[9]. Intact limestone, when slowly injected with sulphuric acid, a common factory waste, swells by ~ 50%, becoming gypsum; a macro-engineering project based on Schuiling's concept could lift the atolls through gradual and unseen underground expansion of rock. Slow upheaval of Adam's Bridge by utilization of Schuiling's intentional 'geochemical macro-engineering' could create an elevated peninsula-like oceanographic barrier. Both rock types are quite capable of becoming reliable foundation material for any kind of major construction affecting Adam's Bridge, such as the future installation of wind and hydro turbines and a trans-Palk Strait railway or highway.

A Palk Strait Power Station, affixed to many bridge-connected atolls at Adam's Bridge, and extending ~ 32 km end-to-end, would have to endure powerful Indian Ocean storms and future infrequent tsunami emanating from the vicinity of Indonesia. The maximum vertical load for Cathcart's proposed wind and hydro turbines is small relative to the maximum horizontal load applied by the overturning moment on the potential foundation materials. In other words, the mechanical integrity of the finished facility would not be determined by the structures imposed on the macroproject site but, rather, by the significantly homogenous and weaker natural and artificial substrates upon which the valuable, mostly metallic installation rests. Normal wind and wave loads fluctuate widely, sometimes cyclically (tides). Wind turbine blades are normally fluttered during adverse meteorological conditions, and normal tidal currents are not powerful enough to cause any serious operational problems. Wind, which is ~ 25% of the normal horizontal load, may sometimes cause ~ 75% of the overturning moment on such structures. Future impacts by high tsunami generated near Indonesia, probably mitigated somewhat by a real-time Indian Ocean Tsunami Warning System[10], may permit timely adaptations of far-distant infrastructure to prevent damage and to ensure unfaltering telecommunication warnings to the people of Sri Lanka and India, as well as those in other countries bordering the Indian Ocean.

In addition to the possibility of using Schuiling's speculative geochemical atoll uplift technique, there is the possibility of using dredge spoil from the Sethusamudram Ship Channel Project (SSCP) to raise the topography of Adam's Bridge and other places where such deposition would prove beneficial to commercial, military and civilian interests[11]. Work commenced on the SSCP during July 2005 and is slated for completion by November 2008; the SSCP is subject to tsunami as well as tidal and cyclone storm surges[12]. The actual environmental impact of the SSCP will be discovered as the SSCP is excavated – two notable on-site oceanographic experts, Rajendran[13] and Ramesh[14], have stated their forebodings concerning post-excavation sedimentation via local currents and cyclone-generated storm waves as well as infrequent tsunamis. Both ends of the SSCP, and ships transiting the SSCP, could be protected from tsunami event-processes by an expensive mobile storm surge dam such as the floating steel Maeslant Barrier for the Nieuwe Waterweg (New Waterway)[15], constructed by The Netherlands during 1990–97. The Maeslant Barrier cost is estimated at 2005USA$598,000,000. Less monetarily costly means of SSCP physical protection for the watery border region dividing India and Sri Lanka has become available owing to the recent R&D progress of materials science[16].

A mainly metallic 12 km-long floating bridge spanning the Strait of Gibraltar[17] has been designed by Eugene Tsui, which would rely on ordinary braided steel cables and massive concrete land-based anchorages, just like those used by suspension bridges[18]. Christo created an aerial artwork[19], 'Valley Curtain, Rifle, Colorado, 1970–1972' which required catenaries from which was suspended an international orange-coloured air flow-interrupting textile curtain[20]. Harris (1915–98) macro-engineered 'valley curtain'. Very strong, securely anchored support cables and impervious suspended technical textile membranes are the essential components of the proposed Anti-Tsunami and Storm Surge Textile Arrestor (ATSSTA) macroproject proposal.

Application of advanced technical textiles and super-ropes composed mainly of carbon nanotubes could permit safe emplacement and use of a pontoon bridge spanning the Strait of Gibraltar. Such a bridge would resemble the span used by Xerxes in 480 BC to support his troops as they crossed the Hellespont! Braided or stranded super-ropes could stabilize a post-tensioned pontoon bridge in a fixed geographical alignment for a long period, especially in a nearly constant 1 m/s eastward surface layer sea water flow. ATSSTA will function much as the floating Maeslant Barrier of the Netherlands with multiple discrete anti-ATSSTA installations designed to block the ends of the completed SSCP, stopping any tsunami entering the Palk Bay and its environs and therefore, also halting the natural redistribution of sediment within the SSCP and Palk Bay. When not in use during weather and earthquake emergencies, the ATSSTA will sit on the seafloor between atolls like the air-raised gates of the new dam soon to guard the sea approaches to Venice, Italy from forecasted storms and predicted tidal surges coming from the Adriatic Sea. ATSSTA, however, will have to be lifted by powered windlasses located on appropriately sited Adam's Bridge atolls built up with selected enhancing deposits of SSCP dredge spoil and the mainland (of India and Sri Lanka) – hence, the vital need for an uncompromisingly accurate Indian Ocean tsunami warning system. At urban waterfronts, where highly valuable port facilities must be protected, floating watergates such as those invented by Johhann van de Noort[21], could be installed as needed or desired by the people of Sri Lanka and India.

The ultimate hydrostatic head supported by a textile (woven or non-woven) is the measure of the resistance to the passage of sea water through the membrane material;

the standard applicable for determining imperviousness to sea water is the hydrostatic pressure test made in textile factories. Several international organizations, as well as many national textile regulatory agencies generally accept the height of a seawater column (given in metric units of distance) as the appropriate validation of a test method primarily intended for dense fabrics and films. (Waterproof and watertight are synonyms in this ATSSTA macroproject proposal.) In the past, resistance to sea water penetration (in ship sails and cargo compartment hatch-covers) has been technically achieved by coating woven textiles with various waterproofing materials; watertight textiles can now be achieved by dense weaving of strong fibres. Multi-axial, multi-ply textiles are bonded in a loop system consisting of one or more yarn layers stretched in parallel; yarn layers can have different spatial orientations and different yarn densities. The combination of multi-directional fibre layers has been proved by scientific laboratories and commercial factory testing to be remarkably capable of distributing extraordinarily high strain forces; multiaxial multi-ply textile structures are dimensionally stable in any direction and exhibit isotropic distribution of stress forces with uniform strain behaviour. Such validated materials will work well in tension membrane water-retaining chamber gates of single or multi-level ship-locks[22].

It is proposed that the ATSSTA be fabricated of KEVLAR (29, 49, or 149) – since 1971 KEVLAR in all its commercial products is a trade-name for Dupont's aromatic polyamides – with a tensile strength of > 3 Gpa and cheaply mass-produced CARBON NANOTUBE with a tensile strength of ~ 16 Gpa[23]. (The ratio of producible CARBON NANOTUBE tensile strength to KEVLAR tensile strength is approximately 16/3, or about 5.) Such extremely strong materials, which are becoming rapidly cheaper to produce and are able to perform as unitary form-active structures ought to be investigated for use in the proposed ATSSTA macroproject. The maximum force exerted on a square metre of KEVLAR by a 2 m-high tsunami should be ~ 2 N/m^2. The characteristic strength of a structural textile or film must have a low probability (~ 5%) of not being reached during the lifetime of the material's use in the ATSSTA and the characteristic load must not have more than a 5% probability of being exceeded during the design life of the ATSSTA. KEVLAR has a failure strain of > 3%, while the failure strain for CARBON NANOTUBE is <6%. Possibly embedded fibre-optic electronics – detectors, reporters and automated alarm actuators – ought to be used to monitor in real-time the stored CARBON NANOTUBE super-ropes and KEVLAR curtains as well as the drape of the fully deployed ATSSTA. Of course, human monitors will be situated in distant or sequestered flood-proof offices and housing, safe from all injurious tsunami beach run-up effects.

Planners of the SSCP – with an estimated final SSCP total cost of 2005USA$500,000,000 – and the commercial and naval interests of India and Sri Lanka involved with the macroproject planning, actual building, and operational management may desire to consider multiple installations of ATSSTA around the Palk Strait to safeguard people and property of both India and Sri Lanka. For example, at several acute bends in the SSCP that will tend to sediment quickly, if only from ship propeller-stirred sea water currents, special underwater ATSSTA-like screens could forestall such long-term hazard to navigation. Unlike the SSCP, ATSSTA can be adjusted as to its optimal location through field experimentation both during and after installation. It can accommodate future climate change. In addition, there may be a real need to install at least one ATSSTA on Thailand's west coast to guard the entrance for a proposed Kra Canal through Thailand which means India and Sri Lanka may have a regional marketing opportunity. There is a future possibility for ATSSTA manufactures at the Strait of Gibraltar, where a barrier made with textiles could afford Mediterranean Sea Basin nations a means to prevent flooding of coastal cities such as Venice, Italy, by a postulated global sea-level rise.

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