Palk Strait power station: A future fixed link on Adam's Bridge?

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The first commercial offshore electricity-generation station, Vindeby Offshore Wind Power Plant in Denmark, became operational during 1991. Could an aggregation of wind turbines (WTs) and vertical axis hydro turbines (VAHTs), placed in a fixed-link structure spanning Palk Strait, cost-effectively supplement the national electrical grids of India and Sri Lanka, and provide other national and international benefits as well?

India-only tidal power macroproject proposals have been well studied[1]. However, recent event-processes cast shadows on two macroprojects: the 26 January 2001 Gujarat earthquake[2] instigates unease regarding the projected Kutch Tidal Power Project (900 MW) and new archaeological objections arise from the discovery of important ancient artifacts in the Gulf of Cambay, where a 1800 MW-generating tidal dam has been foreseen[3].

The width of Palk Strait ranges from 64 to 137 km. Situated between India and Sri Lanka, an 18 km-long chain of shoals almost links the states of Tamil Nadu in India with Sri Lanka. Blessed with the distinctive toponym 'Adam's Bridge', today's mostly submerged atoll barrier may have been a land route for people migrating to Sri Lanka ~50 ka cal yr BP; Palk Strait probably endured its final marine transgression ~9–10 ka cal yr BP. The barely navigable ocean strait is named after Sir Robert Palk (1717–98); however Adam's Bridge seems to have an amazing mythological origin of great antiquity.

The first steam locomotive was built by 1804; In circa 1876, a proposal for a railway connecting India and Sri Lanka via Adam's Bridge had been adduced, according to Francis John Waring (1843–1924)[4]. Sri Lanka and India have little geopolitical friction. The only extant macroproject that most resembles what might be built in Palk Strait is the USA railway, finished in 1938, extending over a chain of islands in the Florida Keys[5].

A seafloor model-explanation of the current littoral condition of Palk Strait indicates little has changed since Waring's geographical synthesis[6]. A report penned by Anita Rao Kashi (*The Times of India*, 11 July 2002 entitled 'India–Lanka bridge in the pipeline', claimed that Sri Lanka Bureau of Investment has prepared a detailed concept study for…' a bridge connecting Danushkodi (India) with Thalaimannar (Sri Lanka).

Hydrological resources of Sri Lanka are insufficient to meet its future electricity demand as well as its domestic water supply and rice-growing needs[7]. Tamil Nadu may require, soon, an inter-basin freshwater transfer, part of the National Water Network, to sustain its future population increase[8]. The PowerGrid Corporation of India is charged with establishing a National Grid to facilitate the sharing of resources[9]. India and Sri Lanka are likely to require new sources of vitalizing power; it is logical to seek such electricity-generation capacity at Adam's Bridge, using WTs and VAHTs, to under-grid and foster 21st century industrialization and urbanization. Petroleum exploration in Palk Strait since 1973 amplifies certain regional geological data. It must be said that creation of a fixed link that both generates and transmits electricity also creates a bombardment target during wartime and terrorist-threatened infrastructure during peacetime.

After conducting a flying trigonometrical survey of Adam's Bridge, scouting for a feasible railroad track route, Waring settled upon a series of bridges crossing Palk Strait that would interfere as little as possible with the existing natural waterways. He excluded from further serious consideration, a causeway or embankment crossing. His greatest trepidation was that the islands forming Adam's Bridge might get eroded, removed or reshaped by the northeast monsoon (December–April) and the southwest monsoon (June–October) in the northern Indian Ocean. Sri Lanka was heavily struck by rare cyclones on 23 December 1964 and 24 November 1978. Macro-engineers have experience in the construction techniques needed to preserve sandy islands exposed to cyclone[10]. Surface ocean currents induced by wind move at ~3% of the wind speed. Waring did not anticipate the tsunami hazard; tsunami funnelled into Palk Strait, reflecting off opposing shorelines and low-lying islands, could become a moving hydraulic jump (bore), capable of causing costly damage, such as shifting bridges from their supporting piers or other artificial impedances. Normal tidal sea-currents, owing to the generally predictable local ocean rise/fall of <0.5 m, move through Palk Strait at ~3 m/s; depending on the speed and direction of the incident wind, sea-current speed can vary markedly.

VAHTs involve fixed blades connected to a slowly revolving solid shaft that drives a gearbox/electrical generator assembly; VAHTs are held in an enclosing housing that fixes the machine in a selected geographical position, and directs sea water flow to the turbine, supporting coupler, gearbox and generator unit, which is air over-pressured to exclude corrosive environmental elements. In this way, all of the expensive electrical equipment can be maintained in dry air. By reducing the cross-section of Palk Strait, the sea-current velocity through any functioning VAHT installation is significantly increased. Under mild weather conditions, with a sea-current of ~3 m/s obtaining a VAHT has a generating capacity of > 6 kW/m^2, according to Gorlov[11]. Palk Strait Power Station (PSPS) can be sited on sand, which has a bearing capacity of 1,00,000–8,00,000 N/m^2, so it would be wise to expend ~0.3–1.8% of the total estimated construction cost of PSPS for geotechnical site evaluation; allowing for ~10% of the cost for iffy marine construction work[12] contingencies is prudent[13].

Some 274 VAHT units are planned for the Dalupiri Ocean Power Plant Project, where a tidal fence employment in the San Bernardino Strait, Philippines would mean that the units must inevitably successfully cope with 65 m/s tropical cyclone winds as well as possible, unpredictable 7 m-high tsunami impacts. Its mere contemplation offers clear indication that macro-engineering believes it has overcome all basic technical challenges for such exposed installations, including tsunami displacement!

Sri Lanka and India suffer under restrictive opportunity conditions owing to their endemic national energy shortages; there is untapped hydro and wind potential in Palk Strait. What if Palk Strait were spanned by ~16 km of VAHTs lodged in a structure permitting a free-flow of its sea water in either direction? What if that realized fixed link were studded with many units of 'Windformer', from Asea Brown Boveri Ltd, a WT specifically designed to survive the high mean winds offshore that translate into high electrical production? Ultimately, macro-engineers can expect WT units with capacities of >10 MW[14]. WT foundations must be designed to forestall any chance of their becoming destructive pry-bars during tsunami impacts.

Additionally, there are other tasks for a PSPS installation: (a) supporting a freshwater supplies pipeline from India to Sri Lanka; (b) carrying a slurry pipeline for Indian coal exports to Sri Lanka; (c) conveying several telecommunications conduits connecting two populations; (d) being a roadbed for a railway such as a maglev or, more speculatively, an evacuated tube transport[15]. I do not recommend the PSPS structure carry a motor highway like the Overseas Highway US 1 in USA, a 170 km-long motor roadway linking Florida Keys islands with 35 bridges, approximately 15% of the total distance. I urge others on scene give this sketched macroproject suggestion some elaborating technical and geopolitical thought[16].

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SCIENTIFIC CORRESPONDENCE

Pollen fertility of interspecific F_1 hybrids in genus *Citrullus* (Cucurbitaceae)

Significant contribution has been made for the improvement of many crops through interspecific crosses. In *Citrullus*, however, such achievements have been meagre. Besides cross-incompatibility between wild and cultivated species, the low pollen fertility of F_1 hybrids is one of the major difficulties found in developing lines with introgression of economically useful characters. Though, two species of the genus *Citrullus*, viz. *C. colocynthis* (wild) and *C. vulgaris* are morphologically closely related, Khosoo[1] reported 30–40% pollen fertility in interspecific F_1 hybrids and Singh[2] reported 48% pollen fertility in natural hybrid, locally known as 'ta-tumba', of these two species. *C. colocynthis* locally known as tumba, is one of the predominant species abundantly growing wild in the hot Indian arid zone. It has the potential to yield one million tonnes of oil-rich seeds from the four major districts of Rajasthan, i.e. Jaisalmer, Barmer, Bikaner and Jodhpur. Looking at the tremendous economic importance of this plant, crosses were attempted between these two species involving two accessions of *C. colocynthis* (GP 177 and GP 3), three cultivars of *C. vulgaris* (RW 177-3, AHW 19 and Kalinga) and four interspecific derivatives (TD 7, TD 11, TD 18 and TD 22). This correspondence discusses pollen fertility and the possible causes affecting it in 20 F_1 combinations, which could lead to appropriate breeding methodology to improve fertility level of the hybrids.

All the nine parental genotypes and 20 F_1 hybrids were examined for pollen fertility in both the seasons, viz. zaid 1998 and kharif 1998. In zaid (April) the range of minimum relative humidity, maximum relative humidity, minimum temperature and maximum temperature was 16–19%, 35–48%, 22.5–27.6°C and 35.0–40.1°C, respectively. In kharif (September) these were found to be 41–69%, 80–90%, 24.3–25.7°C and 31.9–35.8°C, respectively. Five plants of each parent/F_1 hybrid from each replication (total four replications) were examined for pollen fertility. Anthers from freshly-opened flowers were dusted on micro-slides and released in acetocarmine (1%) mixed with a little glycerol and mounted using a cover slip. Pollen fertility was estimated by stainability technique[3].

The pollen fertility in different hybrid combinations has been presented in Table 1.