

Guide to Disaster Reduction on Coasts of the Indian Ocean

Progress Report, 18th April 2005

Paul Grundy, Convenor

This report outlines progress to date and future directions for the Working Commission formed to develop the *Guide to Disaster Reduction on Coasts of the Indian Ocean*. The *Guide* was proposed by the convenor, Paul Grundy, a proposal was developed and it became public at an IABSE conference in New Delhi on 22nd February 2002.

The proposal for the *Guide* and the report on the conference and meetings in New Delhi, with abstracts of papers presented, are appended to this report. These documents have been previously circulated.

To understand the focus of this report it is recalled that there are four phases of response to a natural disaster. The first is disaster relief, the second is disaster reconstruction, the third is disaster management and preparedness, and the last is disaster reduction. The first two phases focus on regions which have experienced the disaster. The third looks at improved emergency response to future disasters to mitigate the adverse effects, effective in all areas. Only the last looks at modifying habitat and infrastructure of all regions at risk such that destruction of life, habitat, infrastructure and livelihood are significantly reduced. The last phase is the focus of the Working Commission.

Developments since the tsunami of 26th December 2004.

The emergency relief phase has effectively ended after three months, except for the further major earthquake on 28th March affecting mainly some islands off the west coast of Aceh. The reconstruction phase has commenced. In Indonesia policy guidelines have been developed (www.e-aceh.org). The problems of coordinating aid, mobilizing local communities in reconstruction, establishing ownership of property and sites where records have been lost, reestablishing livelihood, dealing with ongoing trauma and broken communities and families, and reconciling disaster reduction with the policy of rebuilding with as little change as possible are immense. There has not been enough time to develop best practice for disaster reduction and ways to engage local communities in this.

Formation of a Working Commission

The membership of the Working Commission is evolving with a mixture of structural, coastal and earthquake engineers, meteorologists and geoscientists. At present Australia, Bangladesh, India, Sri Lanka, Indonesia and Japan are represented, but there are some obvious gaps. In the future the Working Commission must be broadened to include social scientists and experts in the reduction of poverty, which is closely linked to disaster reduction.

A much wider circle of associates willing to be consulted on matters where they are expert has been established. These will be listed when the membership of the Working Commission becomes finalized.

Contacts

Every effort is being made to establish links with government, professional and humanitarian organizations which have reason to be concerned with disaster reduction in the designated area. This will be a continuing process.

Links have been established with the following organizations:

Government

Australian Government Department of Foreign Affairs and Trade
AusAID
UN Economic and Social Commission for Asia Pacific Region (ESCAP)

NGOs

Care (Australia)
World Vision
The Foundation for Development Cooperation
RedR, Registered Engineers for Disaster Relief
Engineers without Frontiers

Universities and scientific institutions

ESCAP Tropical Cyclone Panel
Geoscience Australia
CSIRO
Monash University
University of Melbourne
University of Newcastle
University of Wollongong
Bangladesh University of Engineering and Technology
Indian Institute of Technology, New Delhi
University of Moratuwa, Sri Lanka
University of Gadjadara, Indonesia
Tarumanagara University, Indonesia
Building Centre of Japan

Professional societies

International Association for Bridge and Structural Engineering
Engineers Australia
Institution of Structural Engineers (UK)
Institution of Civil Engineers (UK)
Institution of Engineers Sri Lanka
Institution of Engineers South Africa

Further links are planned with UN-International Strategy for Disaster Reduction, UNESCO, Global Alliance for Disaster Reduction, etc.

Guide Development Plan

At present there is an interim Development Plan until such time as the Working Commission is formally established and it determines the final form of the plan.

- 1 Establish regional risk parameters for hazards**
(primarily wind, storm surge, earthquake and tsunami)
Based on latitude and longitude
Requires consultation with sources of geophysical and meteorological information, and initiation of research to fill any gaps.
- 2 Convert hazards into effects on habitat and infrastructure**
Depends on local topography, type of building or utility, spatial dispersion

Requires engineering modelling and analysis
Requires identification of regional forms of construction, including field trips
Some original research will be needed.

3 Establish options for minimizing loss of dwellings, essential services and livelihood

Includes community defence systems, modification or relocation of buildings and services
Requires consultation with communities in various regions and groups experienced in disaster relief and reconstruction, and field trips

4 Establish options for eliminating injury and loss of life

Incorporates the options for minimising losses
Includes community education and use of early warning systems
Requires community consultation in various regions, and field trips

5 Develop strategies for implementing the *Guide*

Requires cooperation with United Nations and government agencies, NGOs concerned with poverty and disaster reduction, and regional groups.

6 Schedule

Recognising that data for some regions and analytical methods determining the effects of some hazards will be slow in completion it is planned to issue the *Guide* in draft form so that it can be tested and used before final completion, the aim is to have a first draft ready in a year. This is contingent upon appropriate funding and commitment of resources. One of the first tasks after formally convening the Working Commission will be to conduct an intensive workshop this year, probably in Melbourne, with financial assistance to delegates from the Indian Ocean and south east Asian states. The aim is to produce a complete document in two years from the start of funding. The document would thereafter be updated as experience in its use is gained.

7 Management

It is proposed to manage the project through a secretariat in Melbourne.
It is proposed to assign financial management to the CSIRO (Commonwealth Scientific and Industrial Research Organisation), which has experience in managing projects of this nature.

Endorsement

During the next months endorsements of the Working Commission will be sought from learned societies and organizations engaged in disaster mitigation to provide the necessary weight to the application for funding.

Funding

Significant funding is needed for the proposed workshop, some research tasks, field trips and secretarial services.

To date discussions have been held with the Australian Government Department of Foreign Affairs and Trade, and with AusAID. Much of the considerable funding available is tied to specific regions where disaster has struck recently. This project looks beyond the recent events to regions which were not affected by the tsunami but which are at risk. It is actually too soon to expect funding through governments while procedures are still being developed to establish priorities and accountability in the distribution of funds.



18th April 2005

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Guide to Disaster Reduction on Coasts of the Indian Ocean

Objective

This guide addresses the needs of coastal communities at risk of inundation from floods, storm surges associated with tropical cyclones, earthquakes and tsunami. These needs include

- The ability to survive inundation from any of the abovementioned causes without loss of life or injury, and with acceptable physical damage to housing and infrastructure, any of the abovementioned events having a return period of 50 years
- The minimization of the loss of life and injury and damage to essential services while accepting significant physical damage to housing and infrastructure, any of the abovementioned events having a return period of 300 years
- The reduction of loss of life, injury and asset damage through the introduction of robustness to structures, communication and evacuation systems subjected to extreme events with a return period greater than 1,000 years.
- The capacity for the communities themselves to implement the disaster reduction program.

Interpretation of these needs will take into account the effectiveness of early warning systems against inundation from any source, as well as rising sea levels in the future.

This guide only indirectly addresses post disaster reconstruction. It is directed to all coastal communities to assist them in reduction of risk from disasters, whether they have been affected by the tsunamis of 26th December 2004 or not. However, some of the recommendations regarding buildings and protection of essential services are relevant to reconstruction.

Use of the Guide

The Guide is intended to be used by coastal communities without the need to seek further professional advice. The recommendations contained in the Guide require the input of the geographic location of the community, local information about the terrain, the location of buildings and essential services within that terrain, the proximity of safe refuges (if available), and details of the construction of dwellings and other structures.

With this information the safety and risks of whatever is being reviewed can be derived from the Guide. If the risks are unacceptable alternative strategies for risk reduction will be indicated.

Collaboration

Production of the Guide requires the collaboration of meteorologists for probabilistic models of cyclones, storm surges, and shore crossings, geophysicists for earthquakes, subsea landslides, volcanic eruptions and tsunami generation, coastal and hydrodynamic engineers to model run up and inundation loads on structures, structural engineers to establish safety and risk of structures, engineers from the regions to characterize regional buildings and infrastructure, and risk engineers to evaluate the options including structural modification, evacuation and relocation, which reduce disaster to an acceptable level of risk.

Support for the production of this Guide comes from many institutions and national groups around the world. The number of participant groups is increasing rapidly so that the Guide can claim international endorsement.

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Report on Technical Visit to New Delhi for IABSE Conference and Post Tsunami Discussions, 17-24th February 2005

Paul Grundy

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Summary

The Indian Group of the International Association for Bridge and Structural Engineering hosted a conference on *Role of the Structural Engineer towards the Reduction of Poverty*, 20-22 February 2005, at new Delhi. Following the tsunami disaster of 26th December 2004, the conference hosts invited me to organise an additional session in response. This session, entitled *Rebuilding Infrastructure – Rebuilding Hope* included three papers:

A D Rao. *Extreme sea levels associated with severe tropical cyclones crossing the Indian coasts*

Jonathan Hinwood. *Design for Tsunamis – Coastal Engineering Considerations*

Paul Grundy. *Disaster reduction on the coasts of the Indian Ocean*

The abstracts of these papers are appended to this report. The papers were well received.

A major action while in New Delhi was development of links to enhanced the development of *Guide to disaster reduction on the coasts of the Indian Ocean* which I suggested was a task for the structural engineer – in close collaboration with many experts from meteorologist to social scientists – with his/her capacity to determine design and upgrade requirements for existing buildings and infrastructure to have an acceptable risk of loss of life, of injury, of damage, of collapse, or of disfunction.

These links were developed through discussions at the IABSE conference. The opportunity was taken to support attendance by Professor Priyan Dias, University of Moratuwa and Society of Structural Engineers, Sri Lanka, and Associate Professor Tahmeed M Al-Hussaini, Bangladesh University of Engineering and Technology. Both are members of the group formed to develop the development of the *Guide* mentioned above.



Tahmeed M Al-Hussaini, Jon Hinwood, Paul Grundy, Priyan Dias

By a fortuitous coincidence the WMO/ESCAP¹ Panel on Tropical Cyclones was holding its 32nd meeting at the same time and venue² as the IABSE Conference. This proved to be an invaluable opportunity to forge links with these bodies in relation to the development of the *Guide*. Not only were useful contacts made to assist in meshing our work with global efforts for disaster reduction, but missing links were also identified where the expertise already exists in relation to the work to be done.

¹ World Meteorological Organization/Economic and Social Commission for Asia and the Pacific

² Habitat Centre, NewDelhi

IABSE Conference

The Indian Group of the International Association for Bridge and Structural Engineering hosted a conference on *Role of the Structural Engineer towards the Reduction of Poverty*, 20-22 February 2005, at New Delhi. The notion that structural engineers have such a role is new to many. This conference revealed just how significant that role is, and sadly, how often it is not recognised. But there were also contradictions. The tension between economic development and sustainability is clearly evident. In India about one third of the people live in poverty, the threshold being defined as two meals a day and 2100 calories for an urban worker and 2400 calories for a rural worker plus some extra for basic necessities. In 1999-2000 the poverty line per capita income per month was approximately USD7.50 in rural areas and USD10.50 in urban areas. Potable water, adequate sanitation and access to services are not mentioned. Of the 600,000 villages in India, some 40% do not have electricity and/or all-weather connection to the rural road network. One estimate of the number of homeless families was 40 million. In New Delhi, close to the seat of government, where the roads are wide and paved, and many taxi drivers and most business men have a mobile phone (mostly ringing loudly during author presentations in the conference), the state of the poor is less evident than elsewhere.

The key areas for reduction of poverty include housing, roads, electricity and energy, water, and disaster mitigation and reduction. One would like to add education and a conviction of the villagers that they can leave the poverty trap.

Affordable housing involves local labour and materials, building dwellings to designs preferred by the occupants, engineered to resist earthquakes and possibly inundation. Thus, “modern” houses with an internal toilet are entirely inappropriate in Indian villages, where the best place for the toilet is outside as far from the kitchen as practicable. C R Alimchandani described housing built in Maharashtra State after the devastating earthquake of 1993 which killed 9,000 and flattened 50 villages. Sadly it requires a disaster to trigger such development. Communities which have not experienced a recent disaster will not have the incentive to “retrofit” existing habitat. Methods have been suggested for retrofitting masonry and adobe structures, but these are only effective while the memory of an earthquake lasts, such as that at Bam, Iran, in 2003, which killed perhaps 45,000.

Building up the road network in India has speeded up in recent years. But it is in China that the centralised administration is implementing a staggering expansion of the road network, planning to build 35,000 km of highway and 102,000 km of rural-urban road linkage by 2020, with a further 50,000 km of highway by 2035. I was compelled to ask at the closing Round Table what thought had been given to a future where the use of oil per capita for transport matched the profligate levels of the USA and Australia. If it did, then surely the world’s oil reserves will run out quickly.

The link between energy consumption, especially electricity, and economic growth and escape from poverty is very strong. Which comes first? Professor Jörg Schlaich in the opening keynote paper stressed the need for electricity generation from renewable energy sources, built with local labour and materials. Sadly, such forms of electricity generation seem less common in developing countries than in developed countries. His own invention, the solar tower, now cleverly modified with heat storage so that it runs at near constant output for 24 hours in the day, lies in bureaucratic mothballs in Australia waiting to start construction.

My own session, mentioned above, appears to have been well received. Prof A D Rao presented a comprehensive analysis of the impact of tropical cyclones and storm surge on India. The topic of loads from storm surges and tsunamis on onshore structures, presented by A/Prof Jon Hinwood, was clearly new to many in the audience. My own paper introduced the *Guide to disaster reduction on the coasts of the Indian Ocean*, now planned to cover all coastal hazards in terms of human safety and survival of infrastructure and habitat. Implementation is clearly the biggest problem, where communities have not been affected by recent disasters. Abstracts of the three papers of this session are attached.

Professor S S Chakraborty and Mr B C Roy, the driving force behind this very good conference, are to be congratulated for its success, and they made their own significant presentations.

Meeting with the WMO/ESCAP Panel on Tropical Cyclones

The coincident meeting of the WMO/ESCAP Panel on Tropical Cyclones enabled the four active members of the group in New Delhi (PG, JBH, PD, TMA-H) involved in preparation of the *Guide*, to meet members of the panel. Discussions were held principally with

Le Huu Ti, Economic Affairs Officer, Environmental & Sustainable Affairs Division, UNESCAP, Bangkok

Dr Qamar-uz-Zaman Chaudhry, Director General, Pakistan Meteorological Dept, Islamabad

Nanette Lomarda, Tropical Cyclone Programme Division, World Meteorological Organisation, Geneva

Md Akram Hossain, Director, Bangladesh Meteorological Dept, Dhaka

The discussions focussed on how useful cooperation would enhance the effectiveness of the work of the Panel and contribute to the development of an effective *Guide*. The Panel is clearly well down the track of hazard exposure and risk assessment, early warning, tropical cyclone tracking and landfall prediction, and damage estimation. The added value brought to this endeavour by applying structural performance criteria to habitat and infrastructure seems clear.

The Panel is able to provide information on tropical cyclone and storm surge intensity, with return periods for various heights of storm surge and wind velocity. It would seem that India is the most advanced nation in the region in this work. (It also has the most exposure, shared with Bangladesh, in the bay of Bengal.)

It was agreed that close communication should be maintained between the groups in future developments. The need for the creators of the *Guide* to develop full communication with UNDP and UN ISDR is abundantly clear.

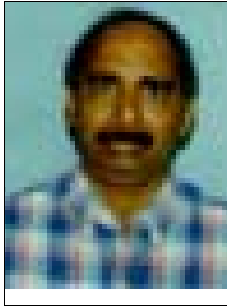
The question of implementation of the recommendations of the *Guide* was again raised. In this, acknowledged to be the hardest part of the whole program, the need for visits to the grass roots, to coastal areas around the Indian Ocean. This in turn revealed the need to develop the *Guide* with proper funding and a secretariat in cooperation with UNDP, regional governments and regional aid agencies.

Paul Grundy

4th March 2005

Extreme sea levels associated with severe tropical cyclones crossing the Indian coasts

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A.D. Rao received his M. Sc. degree in Applied Mathematics from Andhra University in 1978 and Ph.D. degree in 1982 from IIT Delhi for his doctoral work on Numerical Storm Surge Prediction in India. Dr Rao joined the faculty of IIT Delhi in 1982.

The tropical cyclones and the associated surges are very common occurrences along the coastal regions of India, causing extensive damage to life and property. As wind is the main generating mechanism of surge, it is the most important requirement to use actual wind distribution of the cyclone for forecasting surges along the coast. Coastal inundation as result of extreme sea level is the main factor which leads to the loss of life and property. Loss of life may be minimized if extreme sea levels and associated coastal flooding are predicted well in advance.

The head Bay of Bengal region, which covers part of Orissa and West Bengal in India as well as Bangladesh, is one of the most vulnerable regions of extreme sea levels associated with severe tropical cyclones. Shallow nature of the Bay, presence of Ganga-Brahmaputra-Meghna deltaic system and high tidal range are responsible for high water levels in this region. Some parts of Andhra coast, particularly, Krishna and Godavari deltaic regions are also prone to high storm surges. Although the frequency of storms and storm surges is less over the Arabian Sea compared to that of the Bay of Bengal, major destructive surges can also occur occasionally along the Gujarat coast.

Numerical models have been developed at IIT Delhi for the prediction of storm surges and associated coastal inundation in the Bay of Bengal and the Arabian Sea. The noteworthy difference in the formulation of these models, from those earlier developed for the region is the way in which coastal topography of India is represented. A river-bay coupled model is also developed to study the impact of fresh water discharge carried by rivers on the surge amplitude, especially in the head Bay of Bengal where, a large number of inlets including a major river system joins the sea. The presence of such an enormous water ways allows a potentially deep inland penetration of surge originating in the bay. While accurate prediction of surge is very important it is also necessary to have an idea of the extent of inland inundation of surges from the sea, so that the coastal stretch up to which significant flooding is expected can be estimated for the purpose of evacuation of population. Keeping this in view, a continuously deforming shoreline model has been developed and tested for an idealized onshore topography on the east coast of India. In order to predict surges more accurately, location specific models are developed for different regions of the east and west coasts of India. Using these models, the surge heights are simulated for the recent past cyclones and validated with the observations.

A uniform master database on cyclone tracks and its intensity information along with the surge reports is generated from different sources for over a period of 100 years. From the generated database, frequencies of landfall and locations of landfall are determined for each stretch of the coast and hence, constructed synthesized tracks. The maximum pressure deficit (ΔP) is tabulated for each cyclone episode, and using this as a input a suitable statistical analysis is performed to calculate maximum value of ΔP for return periods of 5, 10, 25 and 50 years. Using location specific models for Andhra and Orissa coastal regions, maximum total water level envelop is calculated for each coastal district due to combined effects of storm surges, tides and wind driven waves.

Design for Tsunamis – Coastal Engineering Considerations

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While a major tsunami is effectively an uncontrollable event, there are a number of measures which can be taken to minimise damage and loss of life. In order to implement and innovate such measures it is essential to have a good understanding of the underlying coastal engineering aspects which include wave dynamics, sediment scouring and wave and current loading. The following provides a brief check list of topics.

1. Waves

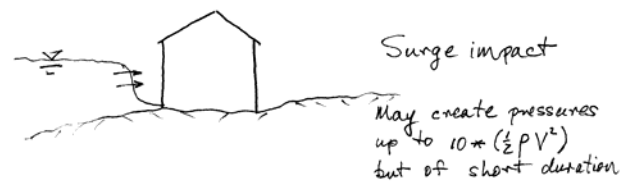
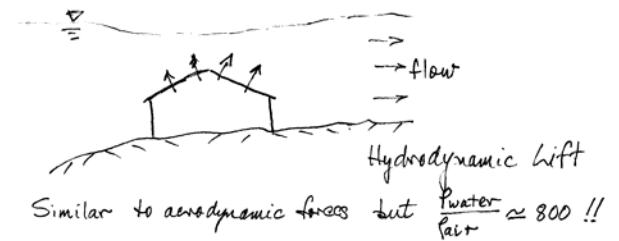
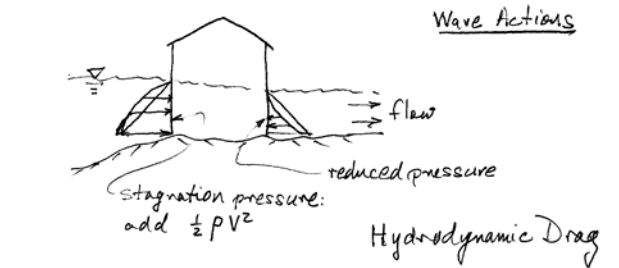
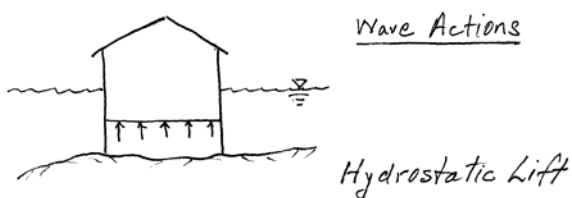
- Generation
 - Landslide A point source but with a land mass behind it the wave energy all goes forward.
 - Volcanic caldera Point source, hence energy falls with radius from source.
 - Tectonic movement Nearby this type may behave as a line source, with negligible drop in energy.
- Propagation
 - Deep water – $c = \sqrt{g y}$ thus in mid ocean $y = 5000\text{m}$, $c = 800\text{kph}$,
Inshore – $y = 50\text{m}$, $c = 80\text{kph}$, but may be faster if very high
 - Refraction – wave crest tends to align parallel to sea bed contours, possible focussing by sea mounts etc.
 - Diffraction – energy spreads around the end of obstacles, possible focussing.
 - Reflection – at the reflecting barrier the wave height is the sum of the incident and reflective wave heights; the whole ocean basin may slosh for days with significant wave heights recurring.
- Transformation
 - In shallow water there is a local increase in height as the energy of the wave is concentrated into a shallow depth and a shorter length.
 - Frequency doubling may occur as the wave reaches the continental shelf if the wave height is large compared with the depth.

2. Wave Actions

- Inundation Causing drowning, water damage to property, contamination of aquifers and water supplies, back-up of sewers, corrosion, blockage of roads and other transport corridors, moored boats broken free or submerged.
- Scour Erosion of roads and farmland, undermining of structures.
- Forces Hydrostatic lift and drag, hydrodynamic drag, surge impacts.

3. Design Concepts

- Wave Reduction
 - Barriers
 - Attenuators
- Action Reduction
 - Ponding
 - Channelling
 - Scour mats
- Damage Reduction
 - Open water plane
 - Breakaway panels
 - Debris minimization
 - Hydraulic performance after structural failure
- Survival
 - Room egress
 - Landward egress
 - Vertical evacuation (how high? hand holds? possibly short duration?)



Disaster reduction on the coasts of the Indian Ocean

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Summary

The great Indian Ocean Earthquake of 26th December 2004 with the devastating tsunamis as triggered a massive and generous humanitarian response in disaster relief. There is need for a corresponding effort in disaster reduction in the face of future cataclysmic events. The disaster risks of the Indian Ocean are reviewed, leading to a proposal for a *Guide to disaster reduction on the coasts of the Indian Ocean*

Keywords: Risk assessment, earthquakes, tsunamis, tropical cyclones, storm surge, disaster reduction

Introduction

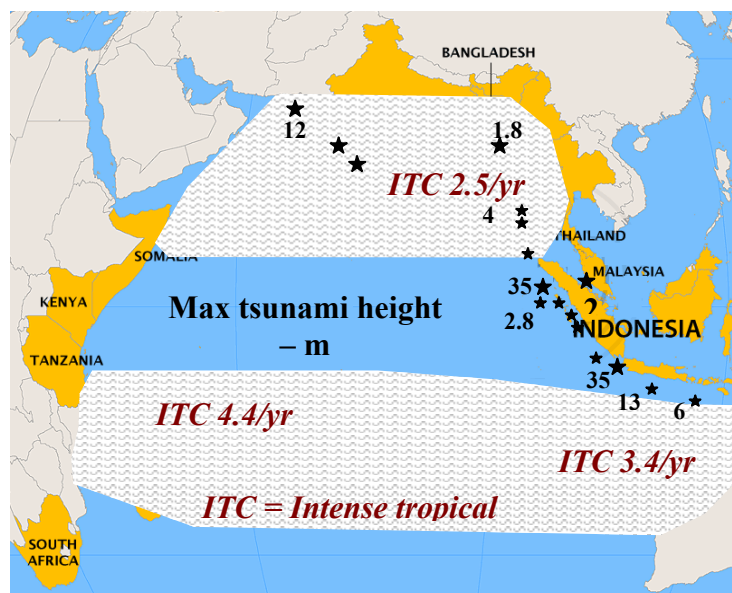
Engineers have used their skills for disaster relief after the great tsunami of 26th December 2004 through groups such as EwF (Engineers without frontiers) and REDR (Registered engineers for disaster relief). Are these shattered communities with or without engineers rebuilding only to be flattened by the next disaster? Are those coastal communities unscathed this time preparing for when their turn comes? How many realise that tropical cyclones, floods, earthquakes and other cataclysmic events kill far more and destroy far more livelihoods than tsunamis?

This paper addresses the issues involved in effecting a reduction of disasters in the face of natural cataclysmic events, with particular emphasis on coastal communities of the Indian Ocean, where the need for action in this regard is as great as anywhere in the world. To address this problem requires (1) a quantified risk assessment by magnitude and return period of all cataclysmic events by region within the Indian Ocean basin, (2) a determination of the effect of those events with respect to depth, velocity and inland penetration of inundation, ground acceleration, etc, as affected by local topology, (3) determination of the effect of such inundation, etc., on buildings and infrastructure, (4) implementation of an affordable disaster reduction strategy depending on the importance of the structure or facility and the risk of loss of life, and (5) implementation of the disaster reduction strategy at the local community level.

Figure 1 – The Indian Ocean basin showing approximately 20 tsunami events in 280 years and frequency of intense tropical cyclones.

Risk assessment

Figure 1 depicts two of the hazards which threaten the coasts of the Indian Ocean. An average of 10 intense tropical cyclones each year can wreak havoc if they come near or cross the coastline, since they can cause storm surges (up to 7 m reported in the Bay of Bengal) coupled with wave action, wind and floods. In the last 50 years they have produced far more deaths and loss of livelihood than all the



tsunamis of the last 280 years, including the most recent. All but one (Krakatoa) of these tsunami events was the result of an earthquake.

Taking into account all causes of inundation it is possible to arrive at the magnitude of storm surge or tsunami with a 50 year return period, 500 year return period and 1000+ year return period. In structural engineering terms the 50 year return period corresponds to the serviceability limit state for design, while the 500 years refers to the ultimate limit state. These are applied to individual structures. However, when whole communities are at risk one needs to consider 1000+ years, dubbed the “disaster” limit state. The concept is used by civil engineers who might design a dam to safely pass the “maximum possible flood” with a nominal 100,000 year return period.

Impact on infrastructure

Tsunami run-up or inundation and storm surge depend very much on topography of the sea bed leading up to the coast, the configuration of the coastline, the topography inland from the high water mark and the presence of obstructions to flow – reefs, mangroves, forestation, buildings, etc. Using coastal position, defined by latitude and longitude, with local topography derived where possible from geophysical databases and supplemented by local knowledge it is possible to determine whether buildings or infrastructure

Using the acceptance criteria of “no deaths or injuries, and no damage” for the serviceability limit state, and “no deaths, limited injuries, some damage but the structure still standing” for the ultimate limit state, “minimised loss of life with critical infrastructure such as hospitals, schools, places of worship, water supply, etc., still functioning” for the disaster limit state it is possible identify which aspects of dwellings and community infrastructure are at unacceptable risk.

Determination of disaster reduction strategy

Disaster reduction strategies to reduce risk to acceptable levels can include raising habitable floor levels of buildings, strengthening buildings for earthquakes and wave forces, building levees around important buildings and infrastructure, or simply relocating villages and towns on higher ground. Unfortunately, many communities are too poor to implement such solutions.

Relocation can be impracticable in populous areas, or in the absence of higher ground, or because of loss of livelihood such as fishing. Then it becomes necessary to develop warning systems of impending inundation which communities recognise and act upon. Low lying areas will need refuges raised above “probable maximum” storm surge or tsunami and appropriate community education simply to save lives. Buildings with upper floors of sufficient elevation can be designated emergency refuges.

Nature’s early warning signs need to be recognised as the first signal for evacuation in case scientifically determined warnings do not reach the ears of those who need to hear them. Banda Aceh was subjected to four minutes of a very strong motion earthquake, which did enormous damage. It should have warned the residents to expect a tsunami within fifteen minutes. Under the best of circumstances it would take seismologists perhaps ten minutes to generate a warning – simply not enough time. More distant parts would have the drawdown of the sea in the harbour as a warning of perhaps 15 minutes. Storm surges rise more slowly so that evacuation becomes possible. But obviously chances of survival are improved by having effective communication of early warnings to those at risk.

Implementation

The production of a *Guide*, difficult as it might be, is relatively easy compared with having it used effectively where it is needed. The implementation will require recognition of the risks of living on the coast at the regional government and local community level, the realisation that these risks can be reduced in an affordable way, and the knowledge of how to do it. At government level the political will to face something which might happen in the future is weak. At village level the community leaders must somehow become aware of the possibilities. It would seem that the best option is to introduce disaster awareness and the commitment to disaster reduction is through community school curricula and the development of teams to inform community leaders and regional governments. Without the support of aid groups such as the UN International Strategy for Disaster Relief this is unlikely.