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TSUNAMI EVACUATION SYSTEM FOR SOUTH COAST OF GUJARAT IN SURAT CITY DUMAS AND GLODEN BEACH

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Abstract: This paper presents the mapping of some cities of South coast of Gujarat for Tsunami evacuation. The various coastal cities of Gujarat have been studied Surat cities are taken as case study. The need for the study is to aware people for the hazard of tsunami and saving maximum lives when tsunami occurs there. In this paper the past historical earthquakes of Tsunami-genic source of Makaran Subduction zone which is responsible for causing tsunami on western coast of Gujarat are studied. The time of arrival of tsunami on the cities of interest is known and the area according topography developed by DEM (Digital Elevation Model) is shown. The elevation of coastal region of 1 to 6 m heights is indicated by different colours in the map and according to distance from shoreline and topography of the ground evacuation maps are prepared. For some cases it is not feasible to use the evacuation route as the large distance is to be determined so at some places vertical evacuation structures (VES) are required to be provided. According to FEMA P646, the suggestions of VES are considered and according to that VES are proposed to some places. Steel content 0.5, 1, 1.5 and 2% has been tested, analysis and it has been compared in the corol mix.

Keywords: Tsunami, Ocean wave. Vertical evacuation, horizontal evacuation, FEMA.

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INTRODUCTION

While even in tsunami prone regions the risk can be quite small, the vulnerability can nevertheless be extremely huge. Managing this risk focuses upon reducing the vulnerability to a satisfactory extent. Hence the primary objective is to save lives. Saving lives means to reduce the heavy impact of incoming waves (hitting persons onto objects, hitting debris onto persons, drown persons)[1]. The risk of being swept out into open sea waters, and the risk of becoming attentive in a collapsing house. While mitigation measures may be installed to reduce the waves' impact, the other main issue remains to evacuate the potentially affected population in time towards safe places.

Usually, in rather populated areas, detailed planning is necessary in order to make evacuation as efficient as possible; hence an evacuation plan has to be set up, implemented and monitored by local decision makers. The main purpose of vertical evacuation structures (VES) is to provide protection during a tsunami. These buildings are especially important where high ground does not exist or where local earthquake sources do not allow people enough time to evacuate, between the moment when an earthquake strikes and the time when the first tsunami wave reaches the shore. Vertical evacuation structures are a fairly new concept that has proven effective; some survivors of the 2004 Indian Ocean tsunami were saved because they evacuated to multi-story reinforced concrete buildings. Several hydraulic model studies have focused on tsunami loading on structures [2, 3, 4] developed design guidelines for buildings subjected to tsunami loading by analysing tsunami force in detail and compiling equations currently addressing loads under flooding. A recent design guidelines document – FEMA P646 published by the US Federal Emergency Management Agency (FEMA) – proposes a practical method to estimate the tsunami design forces at a given locality with a known maximum tsunami run-up height [5].

One of the most deadly tsunamis ever recorded in the Arabian Sea occurred with its epicenter located in the offshore of Pansi in the northern Arabian Sea, about 100 km south of Churi (Baluchistan), Pakistan , at 21.56 UTC (03.26 IST) on November 7, 1945. The earthquake's Richter Magnitude (Ms) was 7.8 [6, 7] the Moment Magnitude (Mw) was revaluated to be 8.1 [8]. In India for coastal construction there are no any exact guidelines available for tsunami loadings.

Even today most of the structures are design according to earthquake loading but none of these is design for tsunami loading. Local authorities, local engineers and common people are also confused regarding tsunami resisting structure design, location and construction. Dwarka which is falling on western and south coast of Gujarat is having highest risk of tsunami. Tsunami generated from MSZ will hit Dwarka first of all. Also the run up height in this region is considerable one for worst damage. For stated target run up height of tsunami waves, arrival time and inundation map of city is most important. The tsunami modelling will based on a historical event, particularly the deadliest historical tsunami, 27th November 1945 far field tsunami generated by a submarine earthquake. Modelling will also consider potential events based on probable to possible earthquakes for far sources associated with the Makran Subduction Zone.

II.METHODOLOGY

The Step wise procedure of evacuation mapping is as following
Step 1: The mapping is stepwise process. In mapping of tsunami first the satellite image showing population is geo-referenced with the SRTM data of Gujarat.
Step 2: The contours are generated in the geo-referenced image. Than the coastal regions are shown using different colours and hazard map is prepared by showing 1 to 6 m heights by different colours.
Step 3: Numerical modelling
Step 4: The details of topography and colours indicated is shown in maps.
Step 5: The evacuation maps are then prepared according to recommendations

III.NUMERICAL MODELING

Numerical modelling of tsunamis is commonly carried out to better understand events that have occurred either during or before historical times. Numerical modelling can also help to predict the effects of a future tsunami [9] has given a series of empirical relationships among moment magnitude (M), surface rupture length, subsurface rupture length, down dip rupture width, rupture area, and maximum and average displacement per event. A leap-frog, semi implicit time stepping integration scheme is used for the tsunami simulations. This allows the use of larger time steps while maintaining stability and accuracy [10, 11]. The present study uses the finite difference code of TUNAMI – N2 to predict wave propagation [12]. The rupture parameters, as provided by Jaiswal et. al. (2008)[13] was used for the source of 1945 earthquake for validation of programme. Along with this some another probable parameters have been taken for the study. Static displacement on the surface of an elastic half space due to elastic dislocation was computed on the basis of equations provided by Mansinha [14]. Based upon these approximations and neglecting the vertical acceleration, the following two dimensional equations (this is called the shallow water theory) were used.

$$\frac{\partial \eta}{\partial t} + \frac{\partial M}{\partial x} + \frac{\partial N}{\partial t} = 0$$

2-D continuity equation

$$\frac{\partial \eta}{\partial t} + \frac{\partial}{\partial x}\left(\frac{M^2}{D}\right) + \frac{\partial}{\partial y} + \left(\frac{MN}{D}\right) + gD\frac{\partial \eta}{\partial x} + \frac{\tau_x}{\rho} = A\left(\frac{\partial^2 M}{\partial x^2} + \frac{\partial^2 M}{\partial y^2}\right)$$

(2D Mass Momentum Equation)

$$\frac{\partial N}{\partial t} + \frac{\partial}{\partial x}\left(\frac{MN}{D}\right) + \frac{\partial}{\partial y}\left(\frac{N^2}{D}\right) + gD\frac{\partial \eta}{\partial y} + \frac{\tau_y}{\rho} = A\left(\frac{\partial^2 N}{\partial x^2} + \frac{\partial^2 N}{\partial y^2}\right)$$

where D is the total water depth given by h+η, τx and τy the bottom frictions in the x and y directions, A the horizontal eddy viscosity which is assumed to be constant in space, the shear stress on a surface wave is neglected. M and N are the discharge fluxes in the x-and y directions.

IV. DATA & METHODOLOGY

The bathymetric grid was built from General Bathymetric Chart of the Ocean (GEBCO) 30 second database and updated with the help of latest hydrograph charts of Gujarat Maritime Board (GMB). Shuttle Radar Topography Mission (SRTM) data has been used to accurately map the land heights (topography). The tsunami propagation states at every 1-min interval are simulated. In this study, model outer domain has a horizontal resolution of 2700 m over the Arabian Sea including the Indian sub-continent (70–260N and 620–800E). The simulation is carried out for duration of 360 min and the Sea states at 0, 60, 120, 150 and 180 min in the Arabian Sea are presented in (Fig-1 to 4). Because of the variability in the bathymetry of the Arabian Sea and the earthquake that triggered the tsunami waves, the wave amplitude varies with the propagation of waves. At t = 0 min, the wave amplitude that is shown in the bar with different colors, next to the simulation Figure, shows red at the point of epicenter. This indicates the wave height is in the range of 5–6 m on the land-ocean boundary. The wave amplitude varies with the forward motion of the tsunami waves. Boundary conditions play a significant factor in the separation of the land and ocean boundary.

The results obtained are configured with the available reports of 1945 Makran Tsunami [13], [15]. Model runs of eighty six earthquake events were simulated for a far source generated tsunami caused by an offshore earthquake. The models show a tsunami wave approaching and starting to hit the west coast of Gujarat 140 to 180 minutes after the earthquake event. Out of 86, one model is in keeping with what has already been seen in Makran Earthquake on November 28, 1945; a tsunami struck the coast approximately 130 mins after the earthquake event

[13]. As it has been suggested that there may be other possible generation mechanisms also [16], [17] .

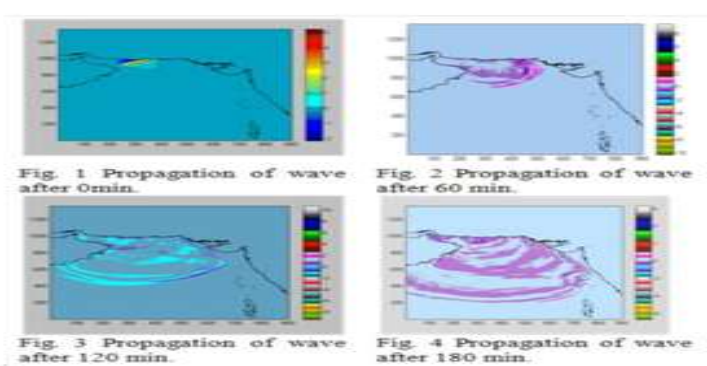

Fig. 1 – Propagation map. (Source :Vikram M Patel et al,.2010)

V. THE VARIOUS STEPS OF EVACUATION PLAN

An evacuation plan has to be generated, using a fact finding and analytical (risk) approach, and subsequently developed in three iterative

Step 1 = first main step basic calculations are undertaken as classical risk and impact analysis. The result should be to reveal the location and the number of potentially affected people, the number and the location of shelter sites. Based on to be defined assumptions, maximum wave height and minimal wave arrival time, appropriate maps will be generated showing whether existing escape routes will be sufficient or not [1].

Step 2 = Further steps of the overall evacuation plan generation process comprise signage of the escape routes and emergency shelters, response instructions to local communities and threatened people, routine exercises for maintaining public awareness,
Evacuation and rescue training, resource allocation, maintenance of the escape routes and the control of the basic assumptions over the years. Hence the second main step means evacuation plan production and dissemination.

Step 3 = Thus the third main step refers to the deployment of the evacuation plan, meaning that an existing tsunami evacuation plan should be monitored over time; variations to the basic inputs or to fundamental concepts of the overall plan should be considered for analysis, examining potential consequences to the existing plan and therefore decide whether iterations of the first or second step above might be required.

VII. THE VARIOUS STEPS OF EVACUATION PLAN

The 2004 Sumatra Earthquake and Indian Ocean Tsunami vibrantly demonstrated the menace of major tsunamis. Interestingly, the majority of reinforced-concrete buildings, except those very close to the shoreline, survived with minor structural damage, even though they were not designed for tsunamis or earthquakes [5]. This indicates that it is possible to design buildings to withstand moderate tsunamis to serve as evacuation shelters. However, development of design guidelines for safe and economical buildings against tsunami is still in its early life.To provide refuge from tsunami inundation, vertical evacuation solutions must have the ability to receive a large number of people in a short time frame and efficiently transport them to areas of refuge that are located above the level of flooding. Tsunami risk is unique in that some communities may be susceptible to far-source-generated tsunamis (longer warning time), near-source-generated tsunamis (shorter warning time), or both. Far-source generated tsunamis generally allow sufficient warning time so that emergency response plans can be based on evacuation out of the inundation zone. Near-source-generated tsunamis may not allow sufficient time for evacuation, so emergency response plans may need to include vertical evacuation building. Tsunami reach Makran zone to Surat nearer up to 150 to 155 min Vertical evacuation structures should be located such that all persons designated to take refuge can reach the structure within the time available between tsunami warning and tsunami inundation. In order to serve effectively as a vertical evacuation structure, it is essential that the area of refuge be located well above the maximum tsunami inundation level anticipated at the site. In this study the said VES is designed for a maximum run-up height as shown in result and discussion

VIII. RESULT AND DISCUSSION

A) The below image shows the vulnerable areas.

When tsunami of wave height 5 metre hits Surat region and its surrounding areas. The area highlighted by cream colour shows the area hazardous by area during tsunami situation.

B) Step wise procedure of evacuation mapping The mapping is stepwise process. In mapping of tsunami first the satellite image showing population is geo-referenced with the SRTM data of Gujarat. The contours are generated in the geo-referenced image. Than the coastal regions are shown using different colors and hazard map is prepared by showing 1 to 6 m heights by different colors. The details of topography and colors indicated is shown in maps. The evacuation maps are then prepared according to recommendations.

C) Surat city maps

The satellite image of Surat city is shown in the sketch. The population density is assumed to be dense in densely populated area as shown in satellite map

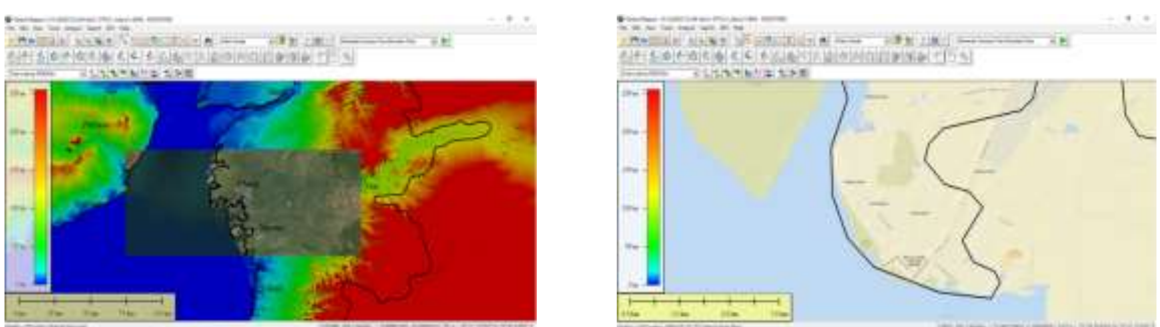

Fig. 2. Geo Referance Image Of Surat City

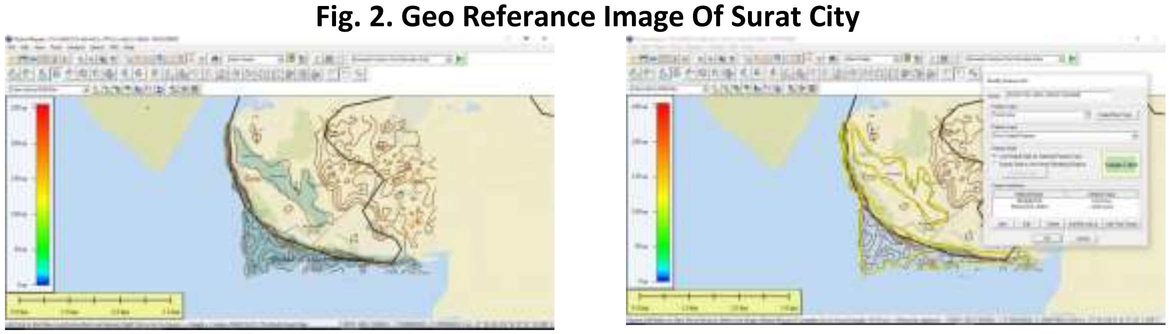

Fig. 3.Countour Mapping Of The Dumas Area With Global Mapper

Fig. 4. Red Dote Indication For Future Possible Vertical Evacuation Building At Dumas Area In Surat City

IX. CONCLUSION

Evacuation is the most important and effective method to save human lives during a tsunami. An important factor in establishing evacuation measures during a tsunami is an accurate representation of the timing of people's responses to the emergency. In this study, with the help of satellite technology tsunami evacuation map is generated for south coast of Gujarat state of for Indian subcontinent. In this study evacuation map of study area is generated in an open source map digitalization tool. Vertical Evacuation Suggestions of study area are derived from further analysis of geo referenced map generally, the research can satisfy the problem. Preparation and Proposed Placement of Evacuation Signs on Road Network with Time and in case of a Tsunami for Coastal city of Gujarat can be done significantly by mapping and using global mapper for placement of points and path of evacuation. The paths are indicated for evacuation by arrow and different ground level according to topography for safe evacuation is shown in hazard map. The concept of VES is explained and suggestions of sites for the same is made in Various maps are prepared that show evacuation routes for Surat city. The hazard maps prepared are useful in case of tsunamis. By application of the mapping tool maps for other cities vulnerable of tsunamis can be prepared.

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