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Geodynamic framework and regional structure as factors affecting the Earthquake Planning of Zakinthos Municipality (Greece)

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Abstract

The Zakinthos town (Zakinthos island, Western Greece) has suffered in the past repeated disasters by earthquakes with most outstanding episode the 1953 earthquake. The high seismic risk is attributed to the particular geodynamic setting of the broad region. In this framework it is considered worthwhile and essential to work out a plan of emergency action in order to minimise the consequences. The organisation of the plan was based on a number of factors, which constitute the problem, the main of which are the geodynamic framework and the given regional and urban stucture. Especially, based on the arising evidence it is found out that the broad area is within a negative geodynamic framework which is characterised by the presence of non favorable geological formations, landslides, settlement, active faults, liquefaction, etc. Furthermore the regional and urban structure of the city was studied. Based on these facts an emergency action plan is proposed in case of an earthquake which includes recommendations for escape ways, assemblage spaces, camps, space for accommodation of public services, areas for rendering first aid service, etc.

1 Introduction

The broader area of the town of Zakinthos is characterised by high seismisity, which is attributed to being in the vicinity of the convergence boundary of the two lithosperic plates; the European one which is being overthrusted and moves to the southwest and the African one which is being subducted and moves towards the opposite direction.

The town of Zakinthos has been many times in the past stricken by big earthquakes (Lekkas [1]), like for example the 1676, 1820, 1893, etc. Particularly in the last earthquake of 1953, the town was laid flat and only three buildings survived from falling down, while at the same time were caused decades of deaths. In the framework of the parameters mentioned above and based on the fact that in the modern times cities have been developed economically and touristically, the earthquake emergency planning and the organisation of the Zakinthos municipality is regarded expedient. The planning is based on the particular geological, seismological, geotechnical, urban pattern and other characteristics, in order to reduce the consequences from a potential big earthquake (Lekkas [2]).

In the present work only some of the above mentioned parameters are addressed. The project deals with the planning of an emergency action in case of a disastrous episode, taking into account the geological risk as well as the urban pattern and regional structure data and mainly appeals the town population.

2 The geological framework

According to the present data (Lekkas [3], Mariolakos [4]) and the field data from the broad area of the Zakinthos municipality, recorded in a scale 1:5.000 the following formations are distinguished (Fig. 1, 2) progressing from the older to the younger ones:

Evaporites Formation. They consist mainly of gypsum and they are Triassic age. Their occurrence is associated in most places with diapyric phenomena. This is the only alpine formation, which belong to the Ionian unit and outcrop in the southern sector of Zakinthos municipality.

Dafni Formation. It occurs in the southeastern part of the Zakinthos municipality. The age is Middle-Upper Miocene.

Kastro Formation. It is composed of clay-marl beds in which occur sandstones. Its apparent thickness exceeds 200m. It occurs in the western sector of the built up part of the town. It is a previously weathered formation, which has often been subject to landslide phenomena.

Gerakas Formation. It consists of calcitic sandstones with marl intercalations in the base of this formation. Its thickness is few tens of meters and has Pleistocene age. It has often been subject to landslides due to removal of support from the underlying formation of Kastro.

Alluvial and eluvial formations. They are made mainly of shale, silt, sand, pebbles and rarely cobbles. Its thickness exceeds 10-15m. The eluvial formations are also loose formations, which are derived from weathering of the underlying geological formations.

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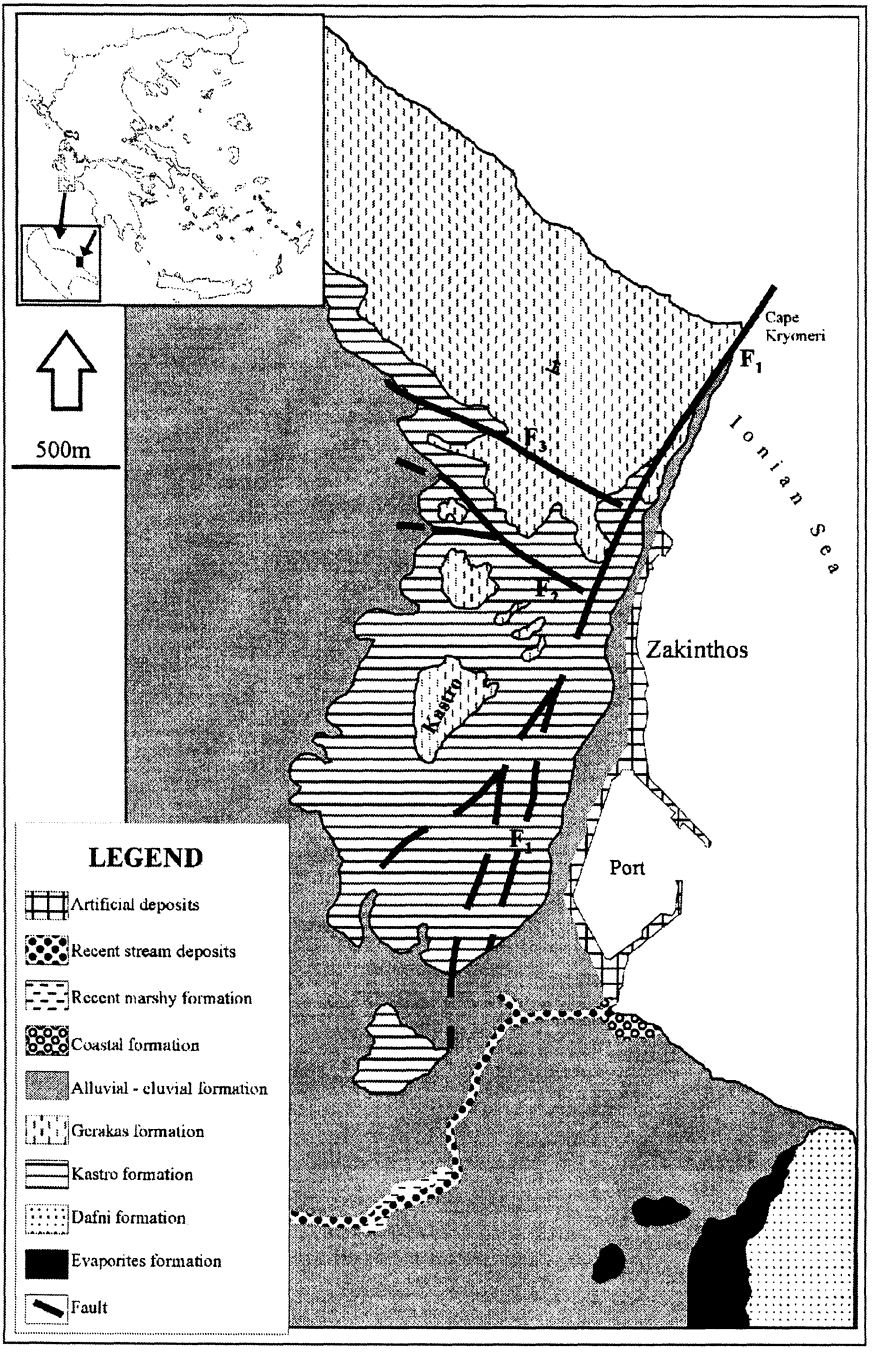

Figure 1: Geological – Tectonic sketch map of Zakinthos municipality.

Coastal deposits. Loose fine and coarse material, which appear along the coastline in limited occurrence. They are often subject to dynamic and static settlement.

Recent marshy formations. They are composed of clay, silt and sand with many plant remnants mainly mossy type. They are subject to liquefaction phenomena, settlement, etc.

Recent stream deposits. Loose clastic material, which develop along stream. They are also subject to liquefaction, settlement, etc.

Artificial deposits. They are observed along the coastal zone and are derived from parts of the sea, which have been banked up with debris from demolished houses from the 1953 earthquake. They are often subject to static and dynamic settlement.

The following fault zones cut the described formations:

Fault zone F_1. This fault zone cut across the western part of the structured area of the Zakinthos municipality and eastern of the Kastro hill. It has a general orientation N-S and initiates offshore to the northeast and cut across the western suburbs off the town. It cuts the formation of Gerakas and Kastro formation. It represents an active fault zone, which was active during Pleistocene and Holocene.

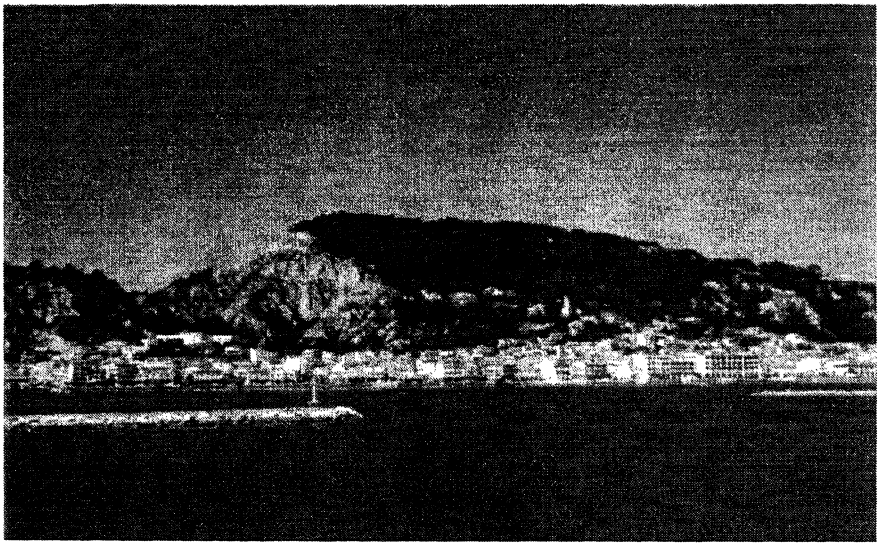

Figure 2: View from the east of Zakinthos town. The Castle hill is formed by the formations of Kastro and Gerakas. The morphological differentiation is attributed to the present active fault zones (F1), while landslide processes often affect these formations.

Fault zone F_2. The general orientation of this zone is E-W. It is an active fault zone.

Fault zone F_3. The F_3 fault zone cuts the beds of Kastro and Gerakas formation. The vertical displacement is few meters. It must have been active in post-Pleistocene times. It is regarded as active fault zone.

In conclusion, in the area of Zakinthos municipality occur formations that mostly behave positively as founding formations, during an earthquake. Additionally the apparent intensive deformation observed in the area of Zakinthos municipality makes the area exceptionally vulnerable, which accommodates seismic foci as well as a receiver of seismic waves from distant earthquakes.

3 Geodynamic disastrous phenomena

In the area of Zakinthos municipality there is a number of potential geodynamic disastrous phenomena which may occur during an earthquake, due to the particular geotectonic, geotechnical and geomorphological features which are observed (Lekkas [2]). These phenomena play an important role in the distribution and the level of consequences, and determine the management plans described below. Such phenomena are the following (Fig. 1, 3):

Active Faults. Disasters that can possibly be caused in the area of Zakinthos municipality due to reactivation of fault zones are expected along the fault trace. Especially negative factor is that the most important active zone (F_1) is located in the western suburbs of the municipality, and along the built-up part of the area. Displacement of the surface plain along the later zone is possible to intensify the damages on the constructions (Fig. 2).

Landslides phenomena. In the area of Zakinthos municipality exist the favorable geological, geotechnical and geomorphological conditions for the occurrence of landslides in case of an earthquake (Fig. 2). The Kastro formation, which mainly consists of clay-marl beds with sandstone intercalations, is a loose formation. Distinct zones, which are characterised by high risk of landslide occurrence, can be delineated by combining the high morphological gradient, which are observed on the slopes of the built-up area of Kastro hill.

Settlements. Potential settlement may occur in the residential area, on the coastal areas where particular formations occur (coastal deposits, artificial deposits) which form an elongated zone along the coastline. The present structure in this particular area has been based mainly on the leveled rubble from the demolished houses from the latest earthquakes which stricken Zakinthos in 1953.

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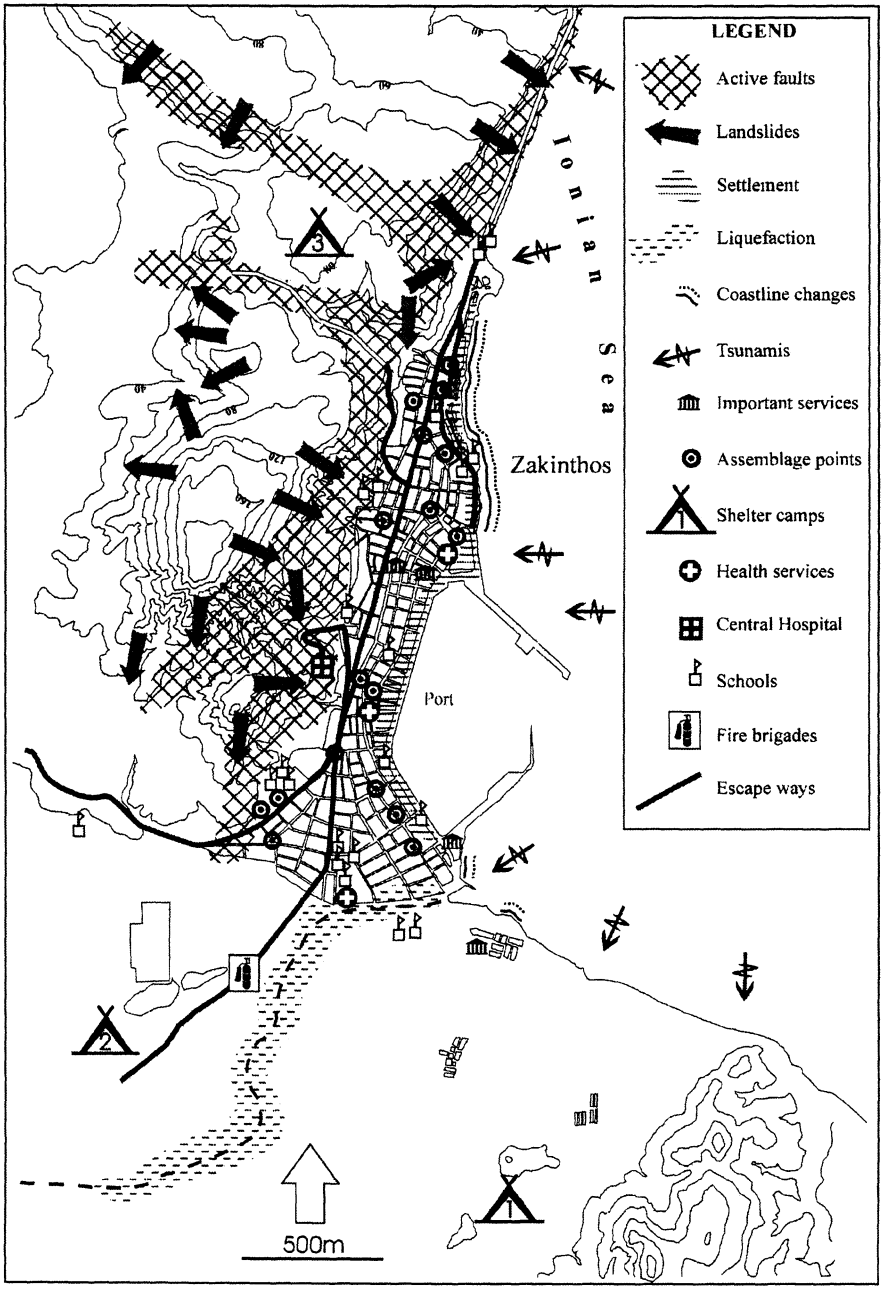

Figure 3: The basic principles of the earthquake emergency planning of Zakinthos municipality.

Liquefaction phenomena. These areas are restricted basically in a zone along and on either side of the main river stage of the drainage network which cut across the area to the south and ends up in a small bay south of the breakwater of Zakinthos town. In this zone, alluvial deposits, marshy formations and coastal deposits cover the area.

Coastline changes. It may occur in the eastern side of the municipality along the shore and especially in the area where the rivers of the drainage network discharge south of the breakwater of the harbor.

Tsunamis. The maximum wave height that has been observed in the past must be regarded as the maximum possible height of a gravity sea wave that can affect the coasts of Zakinthos municipality. The maximum height recorded is 1m (Lekkas [1]).

4 Regional structure characteristics

The case of Zakinthos municipality shows a number of land-planning and town-planning particularities, which affect to a large extent the process of earthquake planning (Fig. 3), as well as the expected degree of success of such a plan. These features can be summarised in the following:

Structure of the town. The town shows basically axial development with a general orientation N-S which is bound to the east from the sea, to the west from the morphological elevation of Kastro (Fig. 2, 3). The public services are situated in the center of the axial structure where the harbor is also located.

Building environment. All buildings of the town have been built after the big earthquake in 1953 with special earthquake provision at least for the know how experience on constructions of that period. They do not exceed 2 to 3 storeys. In many cases were built arbitrary addition of extra storeys, which are characterised by increased vulnerability.

Open spaces. The free spaces are very few and have a small expanse, inadequate to accommodate large population in case of emergency. Exception to these is some school buildings complexes which have a larger expanse. Free spaces with large expanse occur mainly in the outskirts of the residential area.

Transportation network. It is characterised by two to three main road axes, which have a general orientation N-S. All roads of the traffic network have small width, which additionally becomes even more reduced due to arbitrary car parking, resulting in inhibiting the traffic of long vehicles. There is a southern, northern and eastern sector of the network, which links the town with the rest of the island

Touristic character. The land uses as well as the density of the population change significantly from season to season due to the high numbers of touristic visits during the summer.

Health Services. These services, as mentioned before, are mostly situated in the town center. Special mention should be done about the Hospital, which is located in the western part of the town despite the inappropriate location in terms of geodynamics and the additional access problems.

5 Basic principles of the emergency plan

Considering that there is a large number of parameters and planning criteria, the following remarks regarding the basic features of the emergency plan of the Zakinthos town are made (Fig. 3):

Distinction of sections. The area occupied by Zakinthos municipality has been divided in a number of sections. Each of these sections corresponds to one or more secure assemblage places and shelters for the population immediately after a potential earthquake. The number of sections seems excessively high for a town in the size of Zakinthos (6.000 inhabitants which become double during the summer period), however it agrees with the point of view that many spaces must be created close to the residential area for practical reasons as well as psychological reasons.

Emergency evacuation areas. Places, which have been used in the past as assemblage areas, are estates, squares, schoolyards, gymnasiums, parks, playgrounds, churches, etc., which hold many activities, and at the same time are safe places. Some of these have been chosen also for accommodation of first aid service, mainly providing first aid in emergencies of light injuries. It is pointed out there is significant difference in the selection criteria of the assemblage areas for the population (where the people will reside safely for few hours until new directions are ordered) and the shelter camps, and those for accommodation of important services (where residence may last for many months).

Shelter camps. As far as the shelter camps are concerned three safe places are recommended, which have easy access and are cost effective in terms of building the appropriate infrastructure. Moreover close to those places already exist all the required functions as water supply, electricity as well as the sewage system. These areas are located in the southern part of the town and are considered safe in terms of geodynamic hazards. Respective features are present in the areas of accommodation of the Coordination organization as well as other crucial services.

Escape ways. It is initially proposed a road network for escape of the population. However it is pointed out that the central avenue which cut across the town is the main entrance-exit way to the town as well as the main axes of transportation for any aid supply, is in danger of possible falling down of buildings all along the road length and up to the height of harbor. The arbitrary building which is represented by the arbitrary addition of storeys along this main

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road axes, results in the increase of risk since the possibilities of road blockage in case of a disastrous episode increase. Moreover it shows increased traffic mainly during the touristic period and there is serious parking problem all along this road. Additionally, the coastal avenue is in danger of settlement and tsunamis. The northern exit of the central avenue is in risk of landslides, rock falls, and tsunamis. Therefore it is not recommended as an escape way.

Municipal Coordination Committee. Places for accommodation of the Municipal Coordination Committee and the other important services are recommended. It is intended to situate these services as close to the town center as possible so as to serve all the citizens, while at the same time to be secure from potential phenomena, so as to maintain their function even after the occurrence of the disastrous episode.

Heath Service. The town hospital and some other important buildings which host a special category citizens are situated in places which are expected to be especially affected by the earthquake or by expected secondary disastrous phenomena. Based on the present data re-accommodation in long terms of the health service to buildings out of the town with reduced risk is proposed.

Communications. A special case is the town harbor, which shows high risk due to settlement. Considering that so far there is no other alternative, other viable solutions must be examined (infrastructure for fast rehabilitation in case of damage, building a new harbor in another location), taking into account that the harbor represent a determinant factor in the earthquake planning since Zakinthos is an island and the main way of communication/transportation and supply is the harbor.

6 Discussion and conclussions

The data presented above consist part of a broader project on earthquake planning and protection of Zakinthos municipality, which aims at reducing the seismic hazard in an area with increased seismic risk. These data constitute a plan, which can be used by the citizens in case of a potential disaster from an earthquake.

The existence of the plan avert possible confusion and out of control situations which may happen as a result of panic which prevails in similar cases. The plan allows the inhabitants to move safely and to receive first aid services before the arrival of external organized aid in case of a big disaster. It is of high significance for the application of the plan that the official municipal committee and the population perform preparedness tests from under real conditions during the calm period or even during short lived seismic episodes, which often occur in this area. By performing these tests it will be found out firstly the applicability of the plan, and secondly the effectiveness or potential problems.

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It must be pointed out that the proposed plan which concerns mainly the period of the disastrous episode must not be considered as an accomplished and integral proposal. It is simply one link in a series of actions from the state organizations, the town as well as the population and consists of a number of attempts – studies – proposals at prior- during- and post- earthquake stages in order to reduce the potential consequences from an earthquake episode.

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