GIS-BASED EARTHQUAKE DAMAGE ANALYSIS IN THE GREATER CAIRO AREA

Amr W SADEK[1], Ayman SOLAIMAN[2] And Mostafa A BARAKA[3]

SUMMARY

In the present study, a GIS-based earthquake damage analysis system is developed to assess the structural effects of the 12 October 1992 earthquake, that hit Cairo city and its vicinity, on the buildings stock in the greater Cairo area and to review the performance of structures during the earthquake. The essential core data of the system is derived from large selection of structural evaluation reports of 2270 buildings geographically distributed in all districts of the greater Cairo area. Damage state is defined in terms of its type, severity and extent. Structural damage is classified into seismically and non-seismically related cases.

The damage analysis system integrates the spatial data and the attribute data. The spatial data consist of a number of data layers that have their geographic distribution such as the administrative boundaries of greater Cairo, structural inventory, soil type classification, peak ground acceleration, intensity distribution, ground water levels, location of epicenter of the earthquake. The attribute data consist of the information obtained from the investigation reports after the earthquake. The system provides tools to edit, store, retrieve and manipulate the geographic and non-geographic data. Also the system enables to overlay various layers of data together (spatial analysis).

INTRODUCTION

Post earthquake damage assessment and analysis typically involve several parameters which are geographically distributed such as location of the building stock with respect to the earthquake epicenter and soil properties. Many damage features and patterns can only be realized by correlating or overlaying these spatially distributed parameters with the observed damage. For this purpose, Geographical Information Systems, GIS, provide an appropriate platform being adapted to the analysis of relational databases which are spatially distributed. The present paper describes a GIS-based damage analysis system for the Dahshour earthquake, 12 October 1992, that hit Cairo city and its vicinity and caused extensive damage and monetary losses. The information on observed damage after Dahshour earthquake is based on a large collection of investigation reports of 2270 buildings distributed in all districts of the Greater Cairo area. Details of the buildings sample and observed damage are given in reference [1] .

CHARACTERISTICS OF DAHSHURE 1992 EARTHQUAKE

The 1992 event is the first disastrous one to have occurred near Cairo since 1847. The source parameters for this event were reported by the National Research Institute of Astronomy and Geophysics, Helwan Institute (NRIAG), magnitude M=5.3 -location=29.775^{o}N and 31.082^{o}E - depth=30 km, and the United States Geological Survey (USGS) [2], M_b =5.9 - location=29.826^{o}N and 31.228^{o}E - depth=25 km.

Many aftershocks followed the main shock. Figure 1 shows the location of the main shock and the trend of aftershocks distribution, which seems to be the Northwest-Southeast.

[1] *Professor, Structural Engineering Dept., Cairo University (on leave), Email:asadeq@kisr.edu.kw.*
[2] *Information Specialist, RITSEC*
[3] *Associate Professor, Public Works Dept., Cairo University.*

CLASSIFICATION OF DAMAGE

The complete tree of classification of the observed damage implemented in the present study is shown in fig. 2. The observed damage of the buildings after the 12 October 1992 earthquake is globally considered to be either seismically related (where the damage is caused by the earthquake) or non-seismically related (where defects existed in buildings even prior to the occurrence of the earthquake, such as corrosion of reinforcement or construction errors, etc.).

STATE OF STRUCTURAL DAMAGE

Damage is quantified as an index which can be used to determine whether the structure is repairable or should be reconstructed. To formulate the degree of structural damage of the buildings, three degrees of structural damage are synthesized as follows: Severe damage; if the damage in structural elements jeopardizes the integrity or the stability of the entire building, for example when the vertical supporting elements are seriously damaged. Moderate damage; if there is evident damage in structural elements but not to the extent that affects the integrity of the building and still structural repair is required. Minor damage; if there is no damage in the vertical elements and only minor to moderate damage occurs in beams. Severe and moderate damage distributions are shown in fig. 3.

DATABASE CONTENTS

The contents of the database include both geographical and tabular data structured to make the database as efficient as possible. These data layers were obtained from different sources and in different formats.

Geographic Data Sets:
The appropriate data sets for each database component are selected based on their nature and intended use. These data sets are then organized into thematic layers. The seismic damage analysis data layers, which comprise the core of the database of the system, are made of five layers as follows:
1. Administrative boundaries of the Greater Cairo area layer, fig. 4.

2. Soil classification layer
This layer shows the soil classification in different districts of the Greater Cairo area as shown in fig. 5. This data layer represents an average representation of the top five meters of the soil profile. For example, fig. 6 shows a typical soil profile at Heliopolice district, the top five meters consist of different types of sand, accordingly the soil in this district is assumed to be sand soil. Soil type in each district is only representative of the prevailing soil profiles in the respective areas. This layer was generated from large number of soil profiles distributed over the Greater Cairo which can be approximately classified into three types of soil, namely fill area, sedimentation from Nile area and desert area. Overlaying soil layer and the damaged buildings data gives an idea about the effect of soil type at foundation level on the degree of damage that buildings suffered during the earthquake.

3. Peak ground acceleration layer
This layer contains the peak ground acceleration distribution in greater Cairo area. Ground acceleration usually plays an essential role with regard to the structural damage during earthquakes. In the absence of recorded values, peak ground acceleration was evaluated according to Maamoun attenuation formula [2] as a function of the earthquake magnitude and epicenter distance.

4. Intensity distribution according to USGS layer
This layer shows the distribution of intensity in the Greater Cairo area according to USGS investigation [4] after the 12,October earthquake.

5. Location of the epicenter of the earthquake layer
This layer contains the coordinates of location of the epicenter of the Dahshour earthquake according to USGS (29.826^{o}N and 31.228^{o}E).

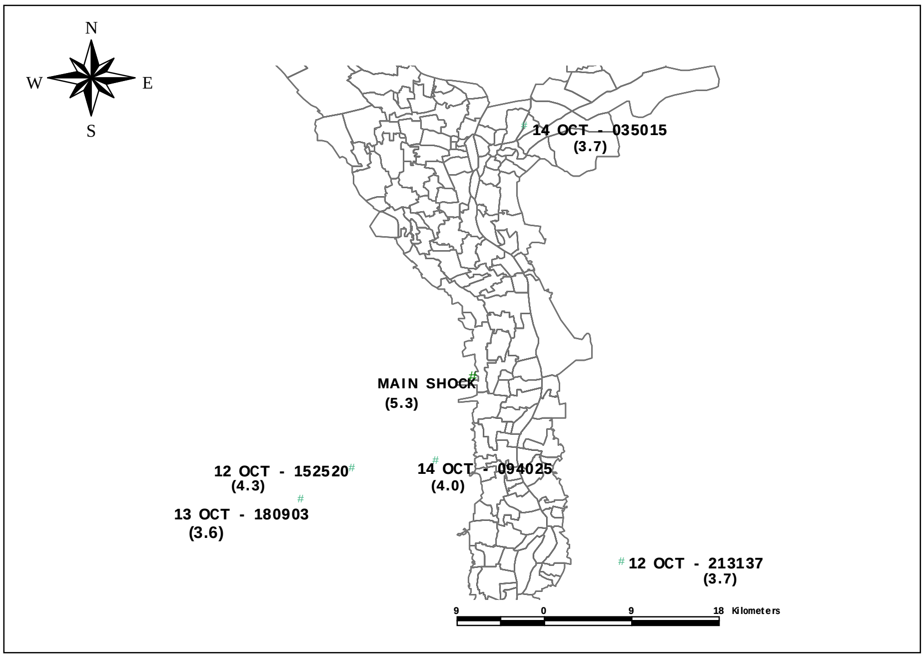
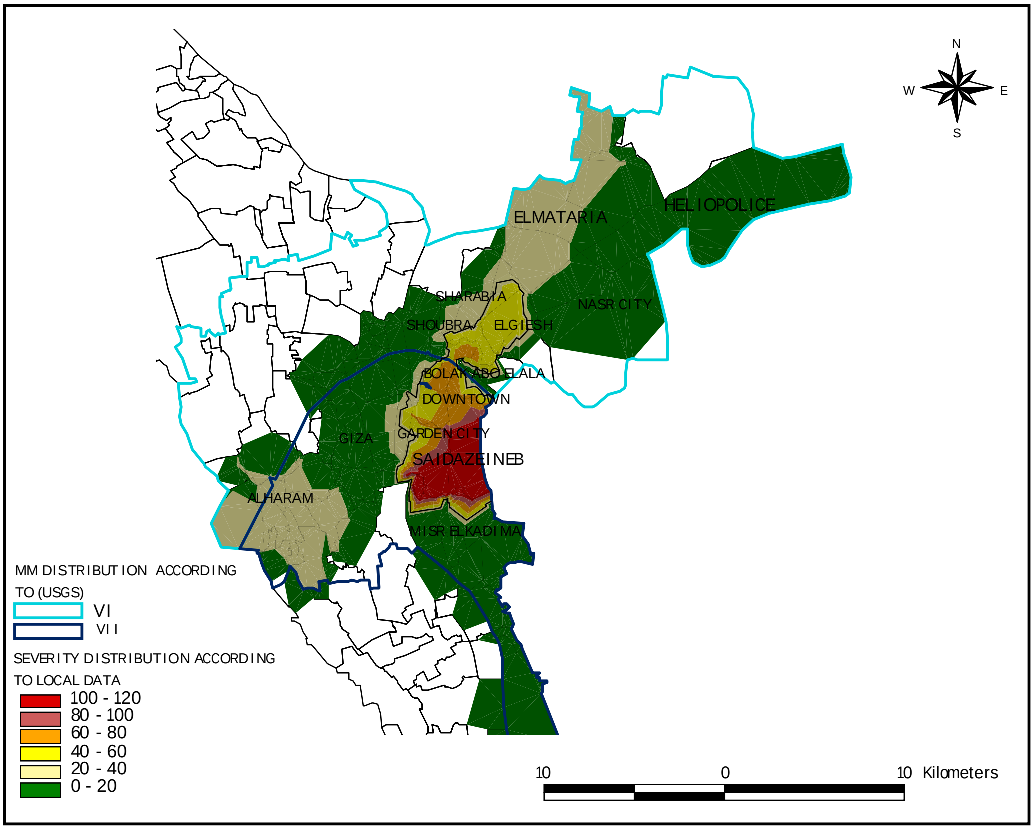


Fig.(1) Location of Main and Aftershocks

- Observed Damage
  - Seismically Related Damage
    - Structural Damage Elements
      - **Bearing walls**
        - No damage
        - Vertical separation at corners
        - Diagonal cracks
        - Cracks around openings
        - Vertical splitting cracks
        - Horizontal cracks
        - Bulging of walls
        - Tilting
        - Combined cracks
      - **Columns**
        - No damage
        - Vertical cracks
        - Horizontal cracks
        - Diagonal cracks
        - Combined cracks
        - Local buckling of reinforcement
      - **Beams**
        - No damage
        - Vertical cracks
        - Diagonal cracks
        - Combined cracks
      - **Foundations**
        - No damage
        - Breakage of semels
        - Subsiding
      - **Shear walls**
        - No damage
        - Vertical cracks near edge
        - Diagonal cracks
        - Local buckling
    - Non Structural Damage
      - **Infill walls**
        - No damage
        - Separation cracks
        - Diagonal cracks
        - Cracks around openings
        - Horizontal/Vertical cracks
        - Combined cracking
      - **Parapets**
        - No damage
        - Horizontal/Vertical cracks
        - Toppling of portions of the parapet
        - Cracking of cornices
        - Total collapse
    - Stairs Damage
    - BLDG-TO-BLDG Damage
      - Tilting
      - Pounding
      - Threat of collapse of adjacent buildings
      - Opening of joints Expansion/ Construction/ Bldg to Bldg
  - Non Seismically Related Damage
    - Corrosion
    - Deterioration
    - Lack of insulation
    - Excessive deflection
    - Construction errors
    - Over-loading
    - High moisture
    - Prior damage
    - Prior tilting

Fig. (2) Classification of Observed Damage



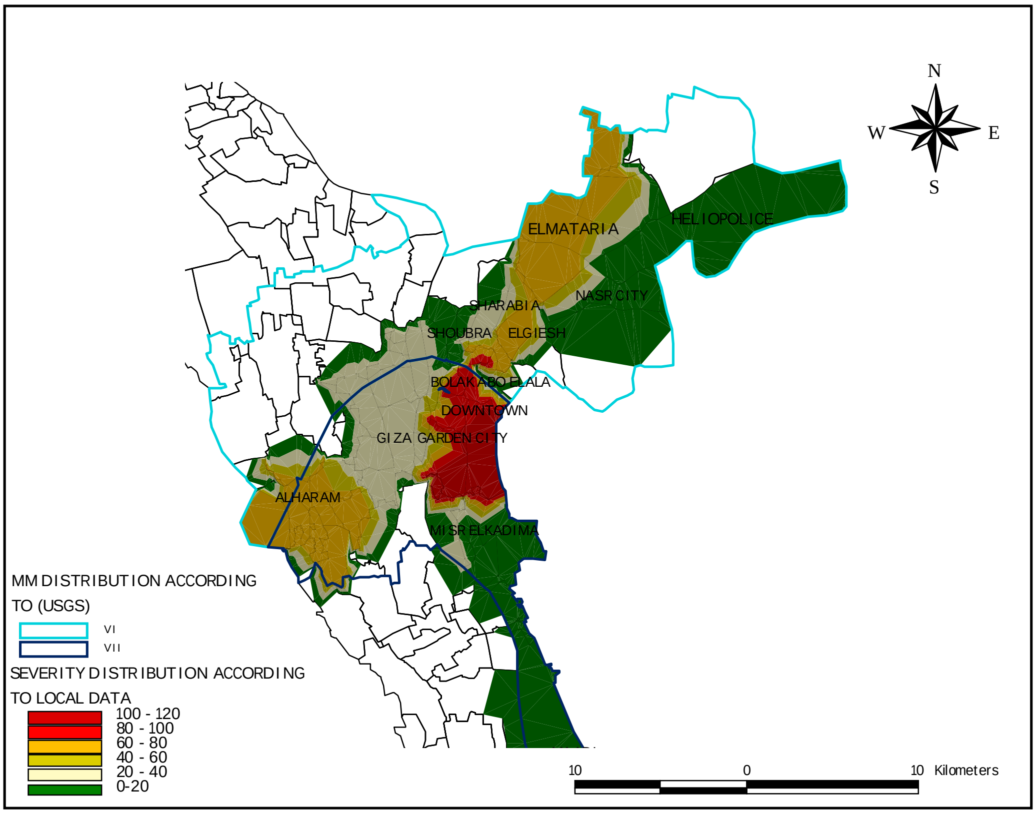


Fig.(3) Severe and Moderate Damage Distribution

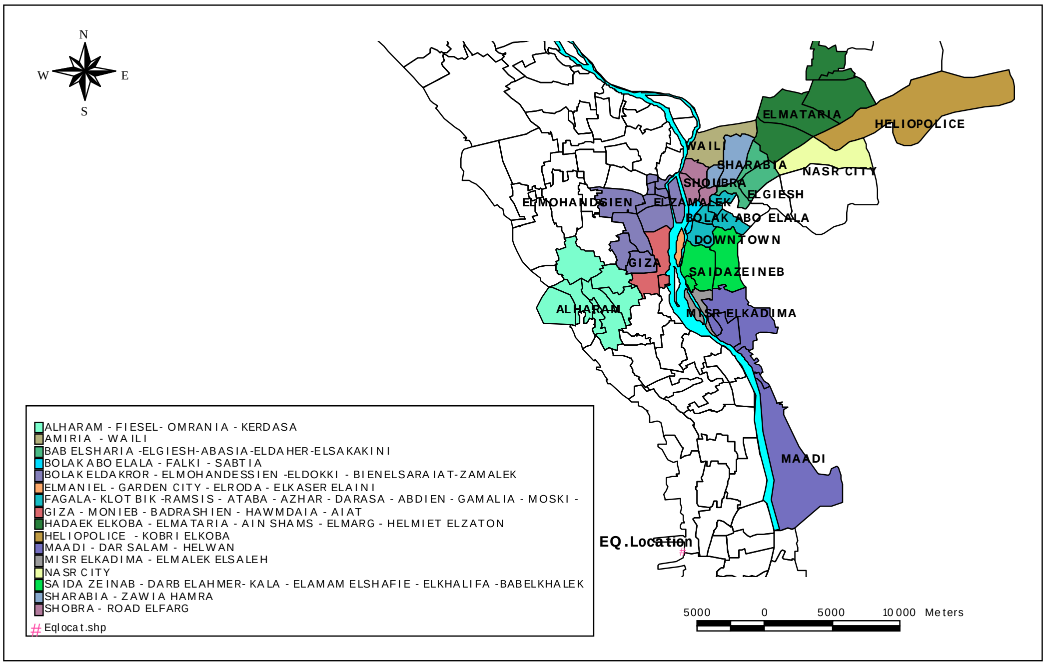


Fig. (4) Administrative Boundaries of Greater Cairo

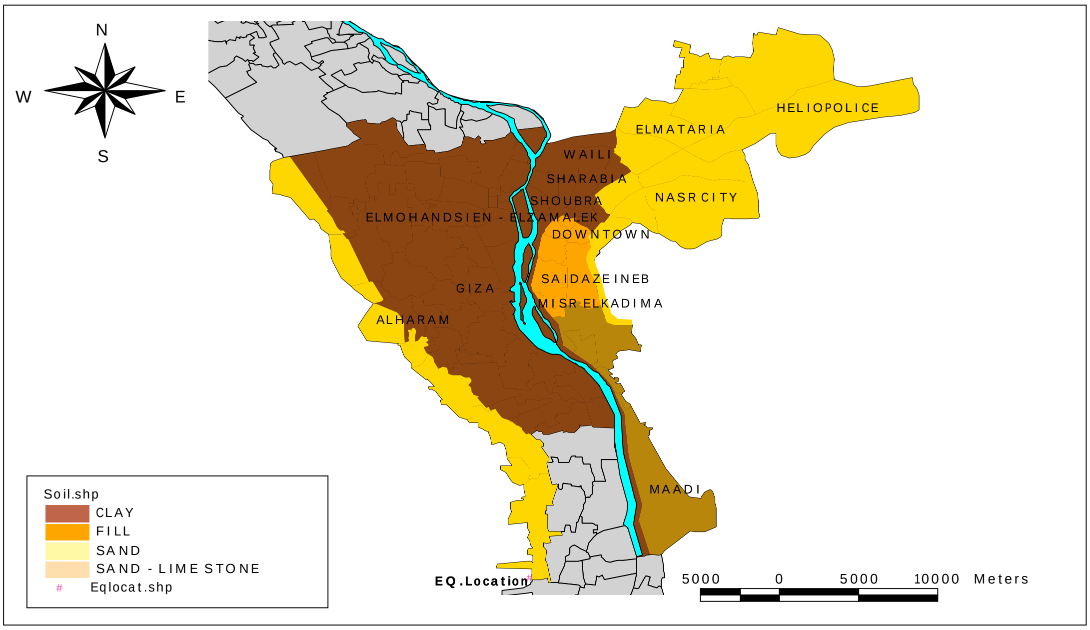


Fig.(5) Soil Classification Layer

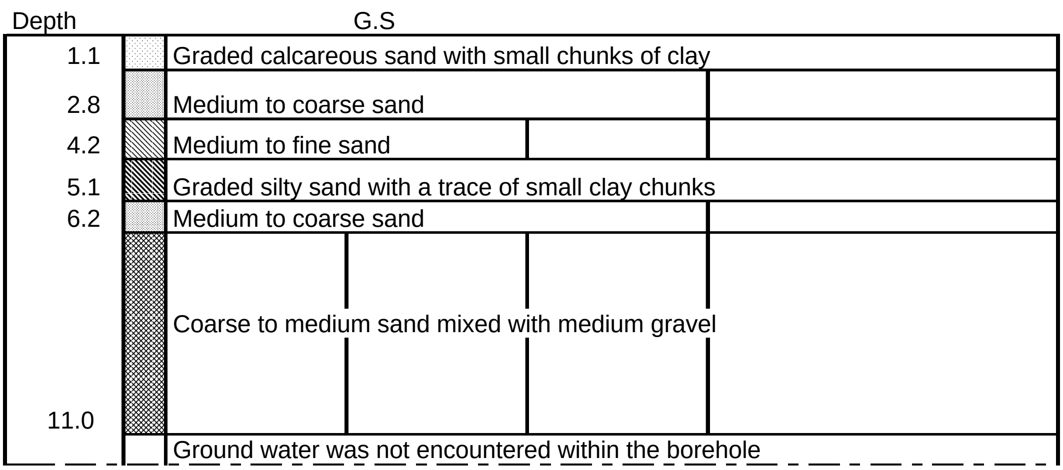


Fig.(6)Typical soil profile at Roxy (Heliopolice District)

Tabular Data:
It is the damage database that contains the information obtained from the investigation reports after the 12 October 1992 earthquake. This data is stored in “DAMAGE.DBF” table. In this database file, each report of one building represents a record, which consists of fields, every field contains a specific piece of information extracted from reports with a predefined format. This table consists of eight groups of fields. These groups are:

1. Data evaluation (reliability of report).
2. Basic Data of building.
3. Damage in structural elements.
4. Damage in special elements.
5. Damage in non-structural elements.
6. Building to building damage.
7. Non seismically related damage.
8. Collapse.

SYSTEM DEVELOPMENT AND APPLICATION

The system is developed using program Arcview [1] by Environmental Systems Research Institute, ESRI.

System Components:
The main components of the system with their functionality, inputs and outputs are shown in fig. 7. In addition to the editing module, which is a tool to update and edit the tabular data in the system, the spatial analysis and damage analysis modules are discussed in the following.

Spatial Analysis Module:
This module performs the analysis of the spatial data and the retrieval of attribute data related to the earthquake. Two main operations are used in this module, the overlay and the neighborhood operations. This module consists of the following functions.

1. Peak ground acceleration analysis

By choosing a value of peak ground acceleration, PGA, the system returns the districts having this range of PGA.

2. Soil type analysis

By choosing the soil type, the system overlays the SOIL layer, the MM layer, the ADMIN layer and the PGA layer and the results generate in the form of the districts with the specified soil type together with the associated MMI and PGA values.

3. Distance from the earthquake

The distance function is used for making the spatial analysis using the distance from the earthquake epicenter. The neighborhood operation is the core of this function due to its capability to evaluate the characteristics of the damage in the area surrounding the earthquake epicenter. As shown in fig. 8, by inputting the distance as 25 kms for example, the outputs are the districts within the specified distance (Misr Elkadima-Saida Zeinab), soil type in these districts (clay – fill), the intensity of the earthquake (VIII) and the PGA value (74-55 gal). A detailed report about the damaged buildings in the chosen district is as shown in fig. 8.
In order to evaluate the damage in any of these districts, some further criteria for the damaged buildings must be entered to the system, these criteria are: structure type (RCF-BW-RCF/BW,..), degree of damage (severe-moderate-minor), date of construction range (zero value indicates that date is not reported) and building height range (zero value indicates that height of the building is not reported).
Similar queries can be made by either entering x and y coordinates or directly selecting from the screen.

Damage Distribution Module:
This module is used to evaluate the damage in each district in the greater Cairo area. It consists of four functions as follows:
Date of Construction, to evaluate the damage in relation to the date of construction of buildings.

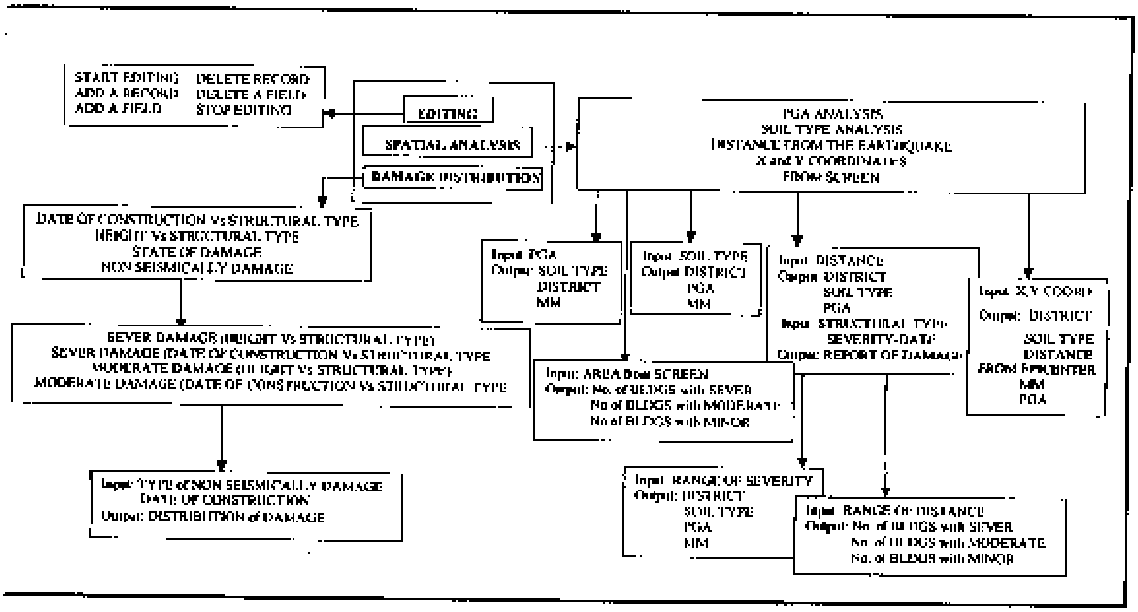


Fig.(7) The Components of Seismic Damage Analysis System

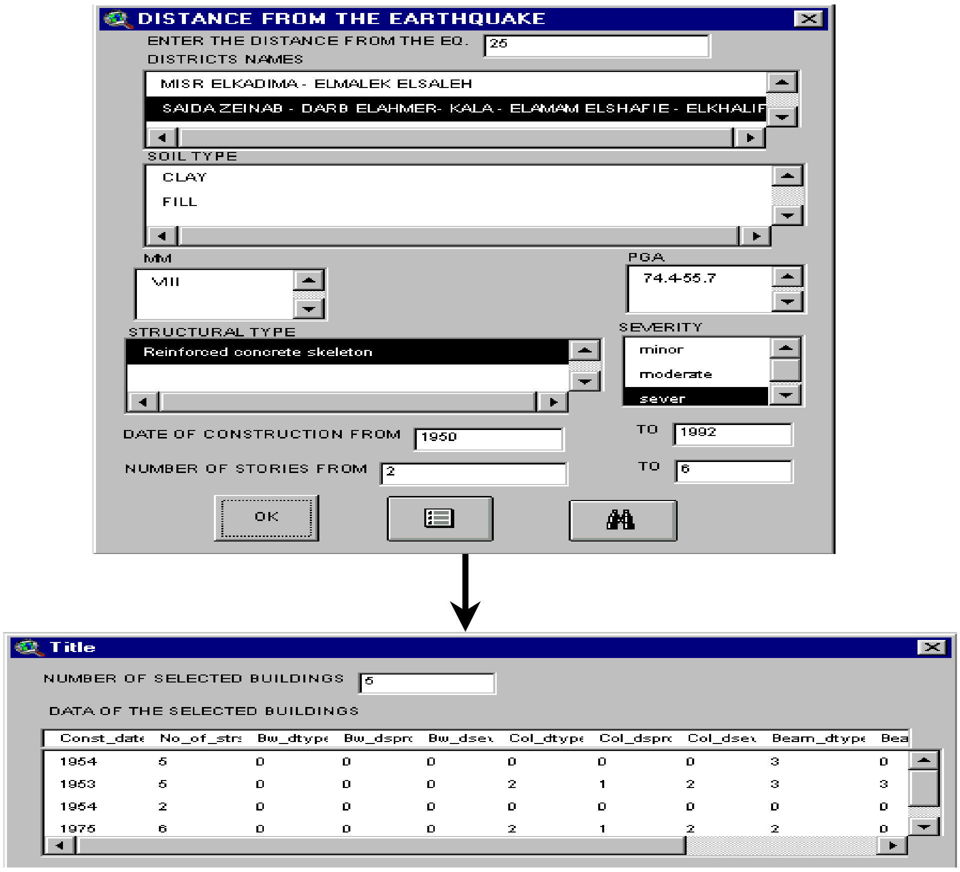


Fig.(8) Example Input\Output Screens of the Distance Function

Height, to evaluate the damage of buildings in relation to the height of the building
State of Damage, this function gives an overview of the severity distribution in Greater Cairo area in relation to the date of construction or the number of stories .

Non Seismically Related Damage,this function provides a tool to evaluate the defects that existed in buildings even prior to the occurrence of the earthquake and were caused by different factors as shown in fig. 9.

CONCLUSIONS

A GIS-based earthquake damage analysis system of the Dahshour earthquake in the Greater Cairo area, has been devloped in the present paper. The present work is the first attempt, up to the authors knowledge, to apply the GIS technique in relating observed earthquake damage and the spatially distributed factors such as distance from the epicenter and soil type. The developed system is proven efficient and provides a prototype framework for spatial analysis of observed earthquake damage.

REFERENCES

1. Arcview, Release 3.0, PC version, Environmental Systems Research Institute, California, USA.

2. Maamoun, M., Megahed, A. and Allam, A. (1984), *Seismicity of Egypt*, Helwan Institute of Astronomy and Geophysics Bulletin, Vol. IV, Ser. B, pp. 109-160.

3. Sadek , A.W. (1997), *Damage Statistics of October 12, 1992 Earthquake in the Greater Cairo Area*, International Journal of Earthquake Engineering and Structural Dynamics, Vol. 26, pp. 529-540.

4. Unites States Geological Survey (1992), *Reconnaissance Report on the 12 October 1992 Dahshour, Egypt, Earthquake*, Administrative Report, December, 14, 1992.

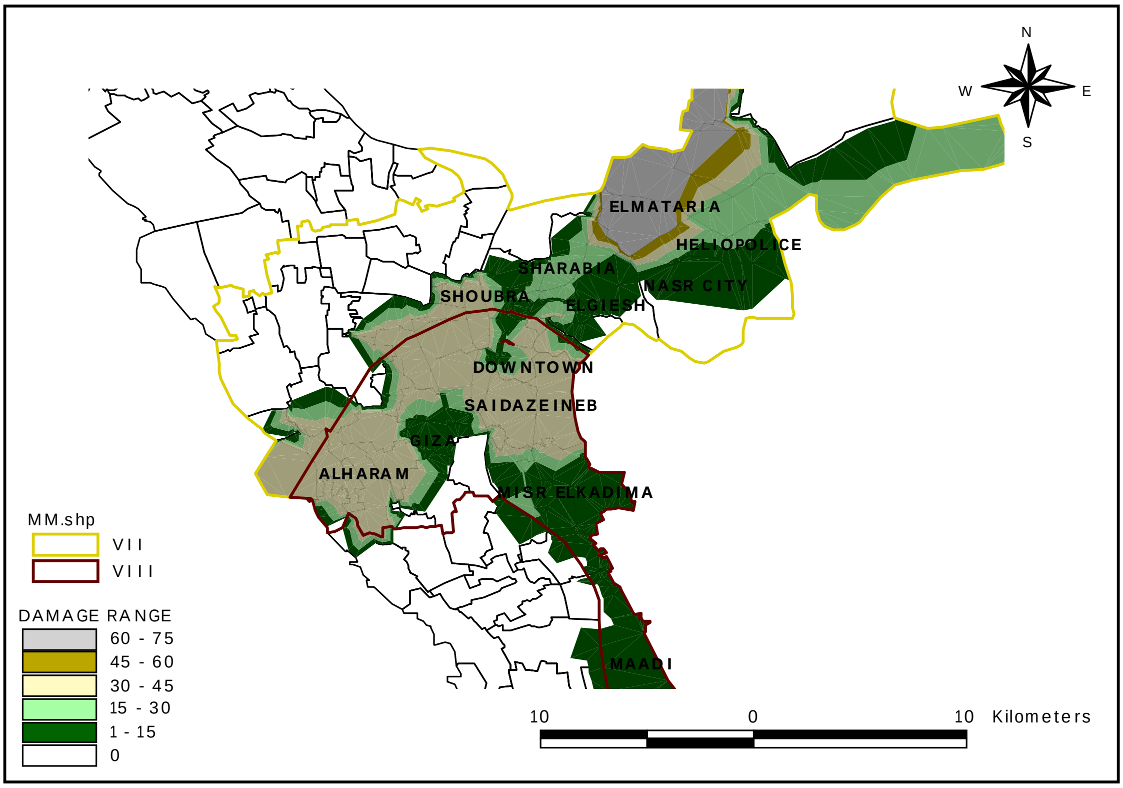


Fig.(9) Example Output Screens of the Non –Seismically Related Damage