AERIAL PHOTO / TRIANGULATION DATABASE SYSTEM FOR KOBE EARTHQUAKE IN 1995

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KEY WORDS: GPS,Aerial ,Triangulation, Orthoimage, DEM/DTM, Three-dimensional CAD Database,
Geotechnical-Engineering Project, Urban-Earthquake Deformation

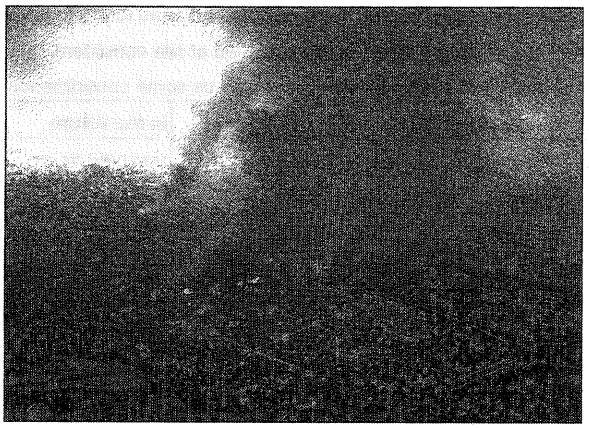
ABSTRACT

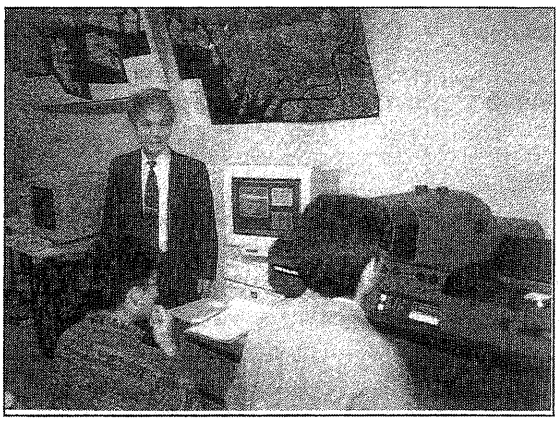
Kobe Earthquake which was measured at 7.2 magnitude in January of 1995 has devastated the densely populated areas between Kobe and Osaka, Japan. Few hours following the earthquake, most of the Aerial Survey Organizations including Geographical Survey Institute(GSI), as well as, several private companies, have scheduled flights over the damaged area. The purpose of these flights was to document, as early and as rapidly as possible, the damage to the area. Flights were made based on the experience of these companies in similar natural disasters including earthquake, volcanic explosions, typhoon floods and tsunami attacks. Flights were planned and executed primarily without the intervention or guidance of any government or public organizations.

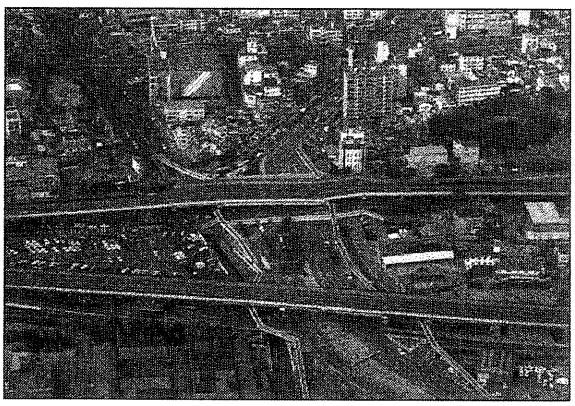
Working group (Deformation Analysis of the Kobe Earthquake, using Digital Photogrammetry) ,in Kobe Earthquake Investigation Commission of Japanese Geotechnical Society ,was organized and guided by Dr. Okamoto to summarize deformation measurement in the area using triangulated aerial photos before and after the earthquake ,to pursue digital Photogrammetric approaches for possible natural disasters and to establish the historical aerial photographic records on advanced 3D CAD based database system(GIS) system, including ground controls, aerial photos(triangulated and untriangulated) and reference maps , such as disaster maps ,geological maps and geotechnical maps.

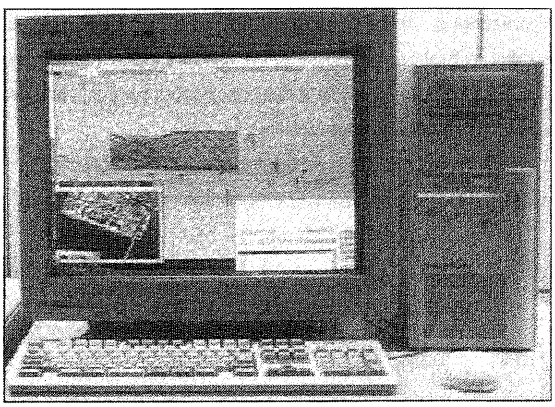
Completion of the " Kobe Earthquake aerial photo retrieval system " in a PC CAD environment has now preserved many existing technical materials, aerial photos, aerial triangulation results and ground controls' records in a timely sense.

Digital photogrammetric researchers and practitioners also recognized the systematized approaches against natural and social disasters , cooperating with GIS systems and advanced surveying technologies, such as GPS surveying and Satellite image photogrammetry.









1. Aerial Photography in Kobe Earthquake and Organizing a WG(Digital Photogrammetry)

Kobe Earthquake attacked the Awaji Island , Akashi bridge under construction and densely populated area; Kobe city, Ashiya city, Nishinomiya city ,amagasaki city and Osaka city in Japan widely and severely at 5:46 a.m. on Jan. 17 1995.

Many photogrammetrists worked for rescuing, investigating and reconstructing the damaged area just after the first news from mass communication media.

Flight crew started to take aerial photos of the damaged area through the dust and smoke , with overlapped scenes and oblique shots, over and over ,for several days, at large and small photo scales (from 1/1,300 to 1/25,000).

Table 1 shows a list of aerial photos taken by 10 organizations just after the earthquake, over the entire area.

Organization	Period ('95)	Photo Scale	No. Str.	No. Photos	Covered Area
Air Graph	1/17	1:10000	2	109	Urban area
Asahi Koyo	1/17-1/21	1:5000-1:10000	37	1710	Kobe Rokko Mt.
Asia	1/17-2/11	1:4000-1:20000	160	4979	Kobe Rokko Mt.
G.S.I.	1/17-2/11	1:7000-1:20000	89	3571	Awaji Is. Kobe,
Hasshu	1/18-1/21	1:8000-1:14000	26	664	Urban area
Kanko	1/17-2/19	1:4000-1:15000	13	900	Urban area
Kokusai	1/17-1/21	1:4000-1:20000	48	1678	Kobe Port Is.
Nakanihon	1/17-1/21	1:4000-1:20000	37	1183	Urban area
PASCO	1/18-2/28	1:1300-1:10000	122	4178	Awaji Is. Kobe, Osaka
Toa	1/28	1:25000	2	36	Kansai Airpo

Tab. 1 Aerial Photos after the earthquake

Working group (Deformation Analysis of the Kobe Earthquake using Digital Photogrammetry) ,in Kobe Earthquake Investigation Commission of Japanese Geotechnical Society ,was organized and guided by Dr. Okamoto a week after the earthquake.

Members collected copies of flight line maps of the whole organizations , and started to digitize them into CAD system.

Parallel with photo mosaicking, the authors planed to produce digital orthophotos out of these aerial photos for initial investigations among geotechnical researchers .

The WG organized the investigation projects as follows;

1) GPS surveying and aerial triangulation of the entire area (10km x50km, from Kobe city to Osaka City)
2) 3D deformation measurement using aerial photos with analytical and digital plotters for pilot areas
3) New configuration of aerial photography, based on GPS navigation system and digital map data, including raster maps, such as geological maps
4) 3D presentation of the investigated results on 3D digital terrain models and texture maps, including 3D animation

Aerial photos in print were sold widely to the municipal, governmental and private companies, such as general construction, real estate and insurance companies from individual aerial survey companies, for getting approximate regional overview.

GPS navigation system for aerial flight was under testing at the period of earthquake, most of the flights were accomplished in the ordinary (experimental) way and aerial flight line maps as well.

Aerial flight line maps were made on existing 1/25000,1/50000 topographical maps, and copied for delivery to the common users.

This process has been modified in such a way that a GPS receiver on an aircraft takes exposure positions and transfer them directly to the PC for CAD system, combined with raster (image) map data.

Leica ASCOT system and Kyoritu VEGA system were used in a testing-modification process after the earthquake.

Most of color prints were used as albums for reference and simple color copies were the most popular media in practice, and even photo color mosaics were used for exhibitions and explanatory meetings mostly, then real productive tools in the future might be digital color mosaics(orthophotos) or satellite image data ,immediately acquired after a disaster.

We continue to propose the entire procedures(manuals) for aerial photography for many kinds of disasters.

With respect to this matter, we have tested the following items;

1) rasterized maps; scanning, editing and printing for CD format
2) superimposition of vector maps on raster maps, orthophoto images within CAD environment
3) Orthophoto production from negative roll films to paper prints
4) Pen computers of A4 or A5 size used at site consistently

Our experience and investigation taught us some considerations .

Consideration Item	at the Earthquake	in the future
Flight budget	voluntary flight	reserved fund
command system	flight office	emergency manual
flight planing	paper map	GPS flight design (aerial triangulation , digital ortho oriented
flight management	pilot, navigator ,cameraman	GPS navigation system
film development ,duplication	separated process	combined process
high precision measuring material	individual storage (depository)	3 major materials database
ground controls	GPS surveying under testing	continuous GPS network
digital orthoimage	simple color print	in production
project plan	individual	public organization

Tab. 2 Aerial photography in future

2. Ground Controls, Aerial Photos and Reference Maps

The 2nd investigation step was fundamental data acquisition of ground controls, aerial photos and reference maps of the damaged area for 3 D deformation measurement by the WG.

2.1 Ground controls before and after the Earthquake

As far as GPS ground controls are concerned, this area was in the transitional stage towards GPS continuous observation stations. Supervisory organizations, such as G.S.I., Kobe city, Nishinomiya city, Toyonaka city and Osaka city have been setting GPS stations. Just after the earthquake , G.S.I. started to install so called dense GPS control network in this area for the continuous observation of the earth surface movement in cm accuracy.

Organization from west	before the Earthquake	Just after the Earthquake	1 year after the Earthquake
Kobe city(544 sqkm)	3D traversing 1st order Leveling	GPS(70)	dense GPS GC (423)
Ashiya city(17 sqkm)	no specified own controls	----------	under planning
Nishinomiya city(99 sqkm)	3D traversing 1st order	GPS(85)	completed
Amagasaki city(50 sqkm)	3D traversing 1st order	----------	under planning
Toyonaka city(37 sqkm)	GPS 1st order	GPS(39) 1st order	GPS(2065) 2nd 3rd order
Osaka city(220 sqkm)	3D traversing 1st order	GPS check(30)	under planning
G.S.I.	3D traversing 1st-3rd Trig. Pt.	GPS(20)	dense GPS GC (250)

Tab. 3 GPS ground controls after the Earthquake

2.2 Large scale aerial photos before the Earthquake

According to the current surveying regulation, most of the municipalities in the damaged area had some sort of large scale aerial photos before the earthquake, for the following purposes. Those zones are quite sparse in shape and documentation are quite individual and diapositives are in different mapping companies based on proprietary contracts.

2.3 Reference maps in the Earthquake area

Reference maps are sold separately, sheet by sheet by different organizations and some sheets were sold out after the earthquake and reprinted after several months.
For rapid investigation most maps were to be prepared in a digital or raster form rather than paper style, corresponding to the forthcoming digital processing.
Many field researchers complained about time consuming data input work. To make the matter worse, a map room in Kobe city hall was crushed, when the building collapsed in the Earthquake.

Organization	Photo (Map) scale	Period	Purpose	No. Photos
Kobe city	1:4000 (1: 500)	1994	Road management Mapping	Approx. 100
Ashiya city	1:4000 (1: 500	1992	Sewerage Mapping	Approx. 50
Nishinomiya city	1:10000 (1: 1000)	1994	Taxation Mapping	Approx. 20
Amagasaki city	1:12500 (1: 2500)	1992	Urban planning Mapping	Approx. 20
Toyonaka city	1:3000 (1: 500	1994-1996	Road management Mapping	Approx. 360
Osaka city	1:10000 (1: 2500)	1992	Urban planning Mapping	Approx. 65

Tab. 4 Large scale aerial photos(Triangulated)

The existing triangulated aerial photos are stored separately in different mapping companies, and not yet handled, as public infrastructure, in a common public depository.

Map type	Scale Projection	Usage	Utilization in Project	No. Map Sheet
General Map	1:1,000,000 Lambert	Active Fault Maps	General overview	1 in 3
Regional Map	1:500,000 Lambert	Active Fault Maps	detailed remark	1 in 8
Topographic Map	1:200,000 UTM	Geological Map	General overview	4 in 130
Geomorpholo gic Map	1:50,000 1:25,000 UTM	Geological Land Use Map	Base Map for Research	25 in 1291 50 in 4383
	1:10,000 UTM Local TM	Digital Base Map FD Map	Disaster Map	20 20
Urban Planning Map	1:2,500 Local TM	Print Map	Detailed Research Map	Kobe
Road Registration Map	1:500 Local TM	Print Map	Detailed Research Map	Kobe

Tab. 5 Reference Maps for the research

Some reference maps, such as geological maps, are used by geological researchers in Japanese Geotechnical Society, with their borehole column charts in a proprietary database system. As opportunity permits we produced raster(image) data of these reference maps in the project.

3. Aerial Photo Retrieval System on PC 3D-CAD and RDBMS

Most important features of flight records were documented into RDBMS in the same PC environment.

3.1 Digitized aerial photos(Exposure stations)

Most of the large scale aerial photos taken before the Earthquake and large and medium scale aerial photos after the Earthquake were digitized on the plotted topographical maps and coded into PC 3D-CAD environment.

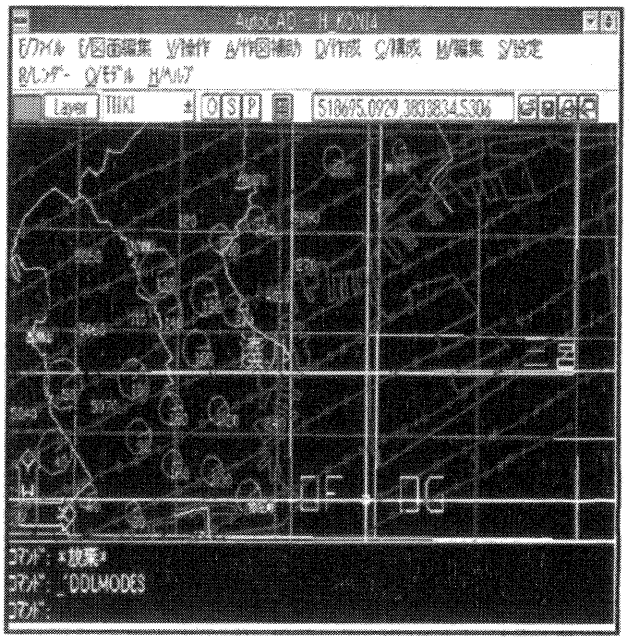


Fig. 6 Digitized flight lines and exposure stations

Background of digitized vector lines and symbols is rasterized topographical maps or vectored digital maps.
According to the range of the area, map projections were unified into UTM 53, using map projection software.

3.2 Attributes on exposure stations

To put additional attributes on the graphical symbols of exposure stations, PC RDBMS(MS-ACCESS) was used with ODBC routines of Microsoft Windows.
Key application for this combination between CAD and RDBMS was AutoCAD Data Extension(ADE).
It realizes 3 types of queries, both for graphical and textual attributes

1) LOCATION(Graphic ENTITIES)
Window,Polygon ,Buffer fence,Circle
2) PROPERTIES
Color ,Area ,Attribute,Layer,Linetype,Textvalue
3) SQL QUERIES
Table,Column Name,Where condition

ADE handles with multiple map sheets seamlessly during querying the above mentioned queries.

3.3 Database tables

"Kobe Earthquake aerial photo retrieval system" consists of 16 tables as follows;

Table Name	Contents	Major fields	No.Data	Remarks
Ground Ctl.	GPS G.S.I., Kobe, Toyonaka	Xb,Yb,Hb Xa,Ya,Ha (Bessel,TM)	736	(National ,Municipal) GCPs
Leveling Pt.	G.S.I., Kobe, Toyonaka	Precise Crust Height	187	w/Digitized Pt. position
Exposure St.	Before & Aft. Earquake	Co_Na,StrNo,Ph_Na,	88+33 Proj. 536/19000	10 Org. from maps
Exterior Ori. Parameters	After Aerial Triangulation	6 Ext. Orien. Parameters	1336	Albany Result
3D residuals	G.S.I.,Kobe, Toyonaka	3D GCPs Movement	440	Based on GPS Pts
Raster Ref. Maps	Geological, disaster,Topo	Image No. of Map	13	Platform of Animation
Image Data	Aerial Photo Ortho Photo	Image No.	35	Platform of Animation
DTM Data	G.S.I. 50m mesh	Map Sheet No.	10	Wireframe of Animation

Tab. 7 Database tables in " Kobe Earthquake retrieval system"

3.4 Query systems

Many icon buttons are prepared for querying the following items.

Query Name	Functionality	Usage	Data type
DM	Digital Map	Background	DXF, DWG
FLC	3D-Studio	Animation	Image Data
Hyoutei_B	Flight Line	Flight Record	DWG
Hyoutei_A	Flight Line	Flight Record	DWG
Kobeopen	open mapsheet	.idx File open	IDX
Zanbox	3D Movement	Parallelepiped	DWG
Tin	3D Platform	3D View	DWG
Suijyun	Leveling Pts	Precise Crust	DWG
Photo	Exposure Sta.	Photo Image	Bmp
Cam	3D Camera Fig.	Adjusted Pos.	DWG

Tab. 8 Query types

3.5 Preparatory retrieval system for disasters

For disasters in possible areas in Japan, we can propose the similar preparatory retrieval system, derived from this " Kobe Earthquake Project

Requirements	Ground Ctl. Pts.	Aerial Photos	Reference Maps
After Earthquake	Data Collection GPS surveying	Material Collection+A.T.	Paper Maps Scanning
In the future	Continuous GPS Observatory	GPS controlled recorded flight	Raterized Maps

Tab. 9 Preparatory retrieval system

4. GPS Surveying and Aerial Triangulation of the entire area

GPS surveying in this area was promoted just after the Earthquake by Japanese association of surveyors, Association of Precise Survey & Applied Technology and Geographical Survey Institute, as re-establishment of Triangular Point Networks in the area. Based on the reestablished(measured) GPS points, aerial photos(1000 photos) after the earthquake, were triangulated, using analytical plotters and Albany bundle block adjustment software. Major characteristics of this aerial triangulation (Kobe Project), supported by the Ministry of Construction(Osaka National Road Management Office) are as follows;

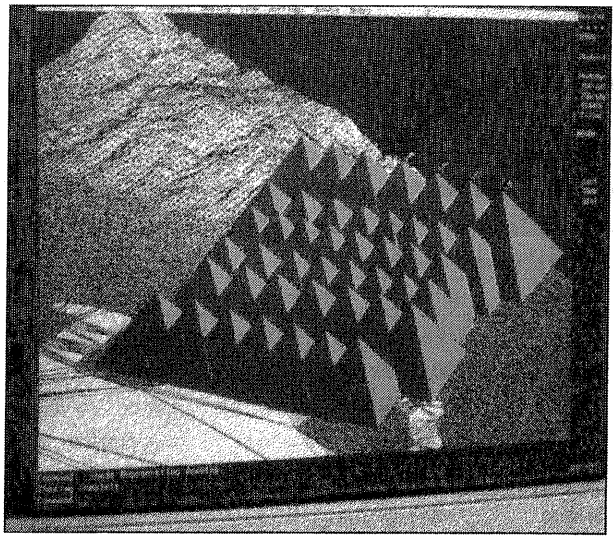
1) GPS Ground Controls 45 pts
2) GPS Network Adjustment
   Closure of sessions(mean) 27 sessions
   dx,dy,dz 0.002m,0.002m,0.007m
   6 common sides 0.012m,0.012m,0.016m
3) Leveling, mostly in urban area 20 mms
4) Photo Scale 1:4000,5000 - 10000
5) No. Photos 608 (1:5000), 315 (1:10000)
6) Camera RC10 f = 153 mm
7) Inner Orientation < 10um, Relative Orientation < 10um
8) Bundle Adjustment
   Est. SDUW 0.01
   Est. SDE px 0.01 py 0.01
   Gplani 0.10 Galti 0.05
   Adj. SDUW 0.01
   Image Residuals(vx,vy)
   0.0045,0.0048(mm)
   Intersection Residuals(dx,dy,dz)
   0.131,0.158,0.071(m)

For the pilot area (Ashiya area)

1) GPS Ground Controls 12 pts
2) GPS Network Adjustment
   Closure of sessions(mean) 21 sessions
   dx,dy,dz 0.002m,0.003m,0.004m
   5 common sides 0.008m,0.002m,0.006m
3) Leveling, mostly in urban area 20 mms
4) Photo Scale 1:4000 (Before),1:5000 (After)
5) No. Photos (1:4000), (1:5000)
6) Camera RC10 f = 153 mm
7) Inner Orientation < 10um, Relative Orientation < 5um
8) Bundle Adjustment
   Est. SDUW 0.01
   Est. SDE px 0.01 py 0.01
   Gplani 0.10 Galti 0.05
   Adj. SDUW 0.01
   Image Residuals(vx,vy)
   0.0040,0.0040(mm)
   Intersection Residuals(dx,dy,dz)
   0.063,0.074,0.066(m)

The results of simultaneous exterior orientation are transferred as CAD drawings on 3D digital terrain model of Kobe area as shown below.

Fig. 10 Triangulated Camera positions after Aerial Triangulation



The results are converted into Database table of " Kobe Earthquake aerial photo retrieval system" for the future reconstruction of the models, using either negative roll films or existing pricked and measured films, at arbitrary time even 100 years after the earthquake.

Japan missed many chances of this type to preserve photogrammetric records in the past major earthquakes and disasters.

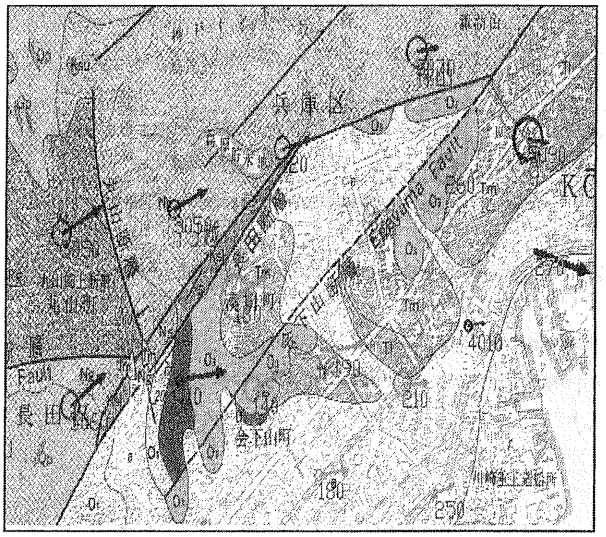


Fig 11 Faults and movements of the Ground controls

The WG has now summarized the results of bundle aerial triangulation and movement of Ground controls in this area. These basic point distribution expresses regional overview of the crust movement explicitly on the existing rasterized geological maps .

This was one of the important premises for forthcoming 3Deformation measurement, using photogrammetric models.

5. Deformation Measurements and their Presentation

Remeasured ground controls in the entire area gave a general idea of the ground movement referring to the existing geological knowledge and rapid field reconnaissance after the earthquake.

5.1 3D Photogrammetric Deformation Measurement

There were many active faults newly found in the strongly shaken belt zone. And the WG selected some representative areas with different types of materials for measurement. and found some distinct phenomena in the areas.

	Before	After	Remarks
Ashiya (9 sqkm)	1/4000 photos 800 check pts (mainly Road Painting) 900 Manholes	1/4000 photos Leveling on Manholes (12000)	3 major active faults Large scale triangulated photo
Eastern Kobe(6 sqkm)	1/4000 photos 200 check pts (mainly Road Painting)	1/4000 photos Demolished Bldg(3D) Liquefied Area (Polygon)	3 major active faults
Toyonaka (6 sqkm)	1/3000 photos 460 check	1/3000 photos 460 check pts	Butunenji fault 1/3000 photos
WesternKobe (10 sqkm) Nishinomiya (12 sqkm) Itami (12 sqkm)	1/2500 map	1/4000 photos Demolished Bldg.(3D), Liquified Area(Polygon)	2 newly found active faults; Harbor area + major faults; (Itami fault) not active
Osaka harbor (20 sqkm)	1/2500 map	1/10000 Photo Liquefied Area	slight effect

Tab 12 representative research zones

5.2 3D presentation of deformation measurement

Measured deformations of controls, height points and 3D objects are expressed first on a Planimetric (raster ·vector) maps.

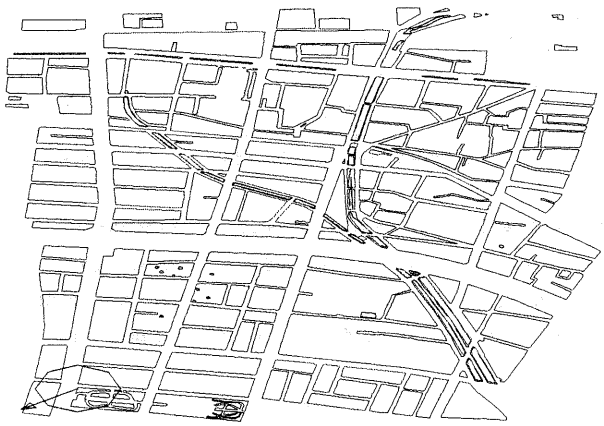


Fig. 13 2D presentation of deformation residuals

Digital Terrain model of this area is constructed from 50m mesh derived from 1:25,000 topographic maps.

This 3D platform was used both for re-projection of planimetric digital vector maps and for creation of 3D textured image of geological map, expressing correspondence between the amount of deformation and existing faults and strata.

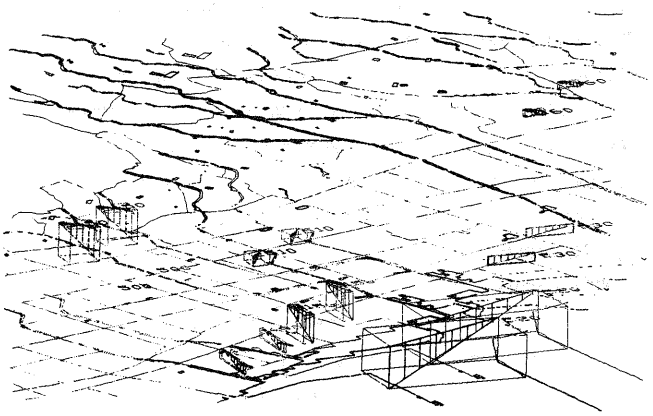


Fig. 14 3D residuals in parallelepiped shape

For 3D presentation of the residuals we created (vector+circle) combination and 3D parallelepiped to show the individual amount of residuals of the points, in the following figure.

6. Conclusions and Remarks

The entire Photogrammetric investigation in Kobe earthquake has been accomplished with some newly created methods and approaches, such as digital flight line - exposure station drawings and database, GPS+aerial triangulation processing and 3D platform expressing residuals and deformations.

The most essential aspect of the project was the cooperation between photogrammetrists and geotechnical engineers, geologists in the common research field.

" Kobe Earthquake aerial photo retrieval system" itself is a kind of first applications, GIS consisting of 3D-CAD and RDBMS on PC environment, using image data maps.

It is also requested to be an urgent emergency system for expected disasters in the field of mapping and surveying.

Acknowledgment

The authors appreciate sincere cooperation of the municipalities, which supervise controls and aerial photos in the respective cities.

References

1. Kobe Earthquake Investigation Commission, Japanese Geotechnical Society; Hanshin - Awaji daishinsai(The great Hanshin - Awaji Earthquake Disaster) Investigation Report , 1996.3

2. Geographical Survey Institute ; Journal of the Geographical Survey Institute(1995, Vol.83) 1995.5