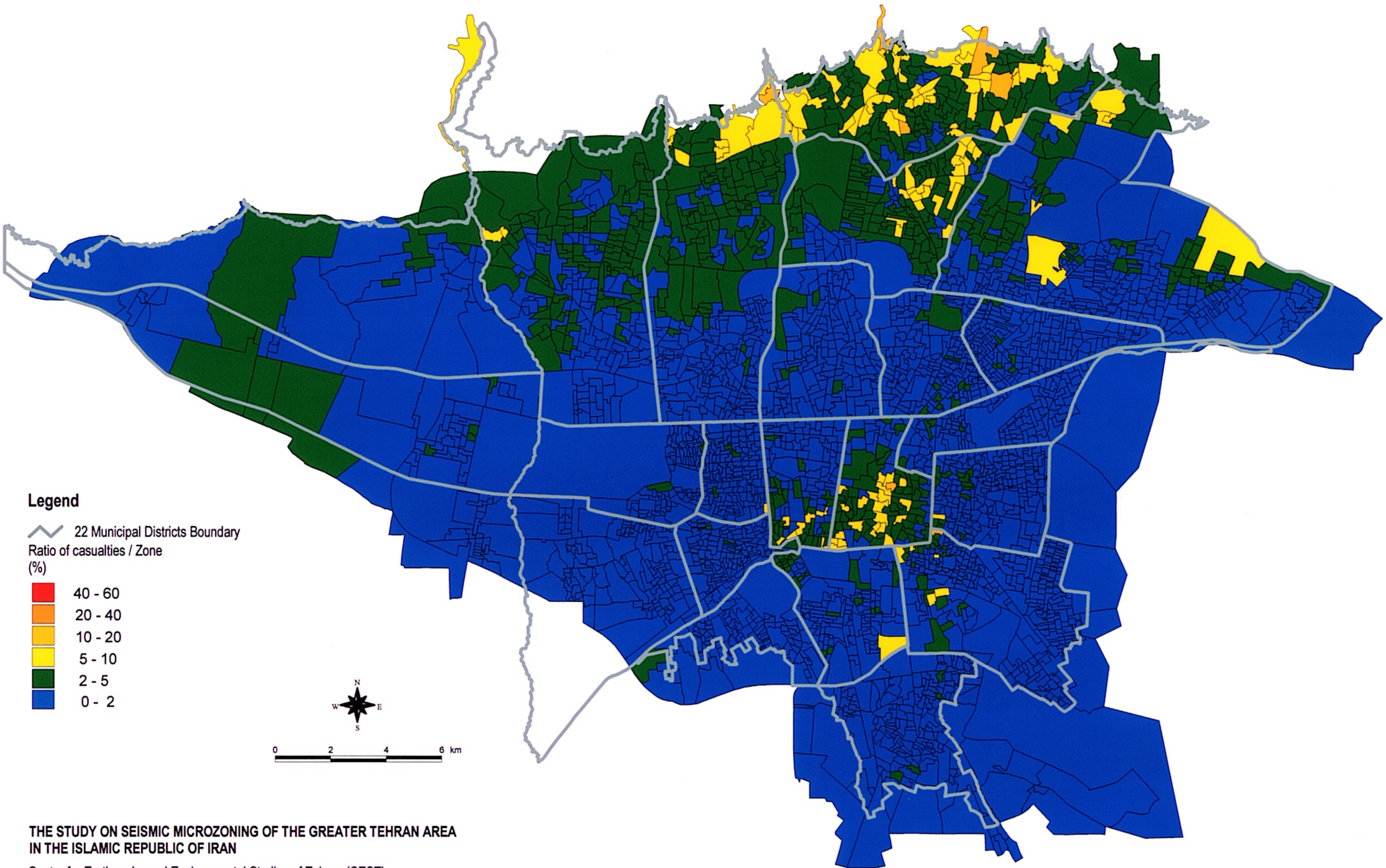
Figure 4.2.21

Casualty Ratio Distribution - Night Full Rescue Work (NTF model)



THE STUDY ON SEISMIC MICROZONING OF THE GREATER TEHRAN AREA IN THE ISLAMIC REPUBLIC OF IRAN

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Japan International Cooperation Agency (JICA)

4.2.3. Validation

Coburn and Spence (1992) surveyed worldwide earthquake damages to identify the relationship between building damages and human casualties. The relationship is shown in Figure 4.2.22. The general trend of the relationships and the results of the Study are added onto this Figure. ' Building damages' consist of only seriously damaged and collapsed buildings, to the exclusion of buildings destroyed by fire or tsunami.

In cases where the number of damaged buildings is 1,000, the distribution of fatalities will range from zero to 1,000. This range of distribution decreases as the number of heavily damaged buildings increases.

The most serious earthquake resulting in the largest number of casualties of the century was the Tang Shan Earthquake in China in 1976, killing 240 thousand people. The data are not plotted here because the number of damaged buildings is unknown.

The result of calculation in this Study will vary in terms of the night-time or daytime occurrence of the earthquake, depending on the types of emergency rescue activities available. Then the number of people killed is expressed as a range of figures.

Four types of scenario earthquakes are prepared in this Study. In all cases, the relationship between the number of damaged buildings and the number of dead people agrees with those of past earthquakes.

In the case of the Mosha Fault Model and the NTF Model, this relationship is closer to the lower limit of the general trend shown by the broken curve. In the case of the Ray Fault Model, the relationship is closer to the upper limit of the general trend. These tendencies correspond to the phenomenon of wide distribution of vulnerable buildings resulting in high death ratios per single building in the southern part of the city of Tehran.

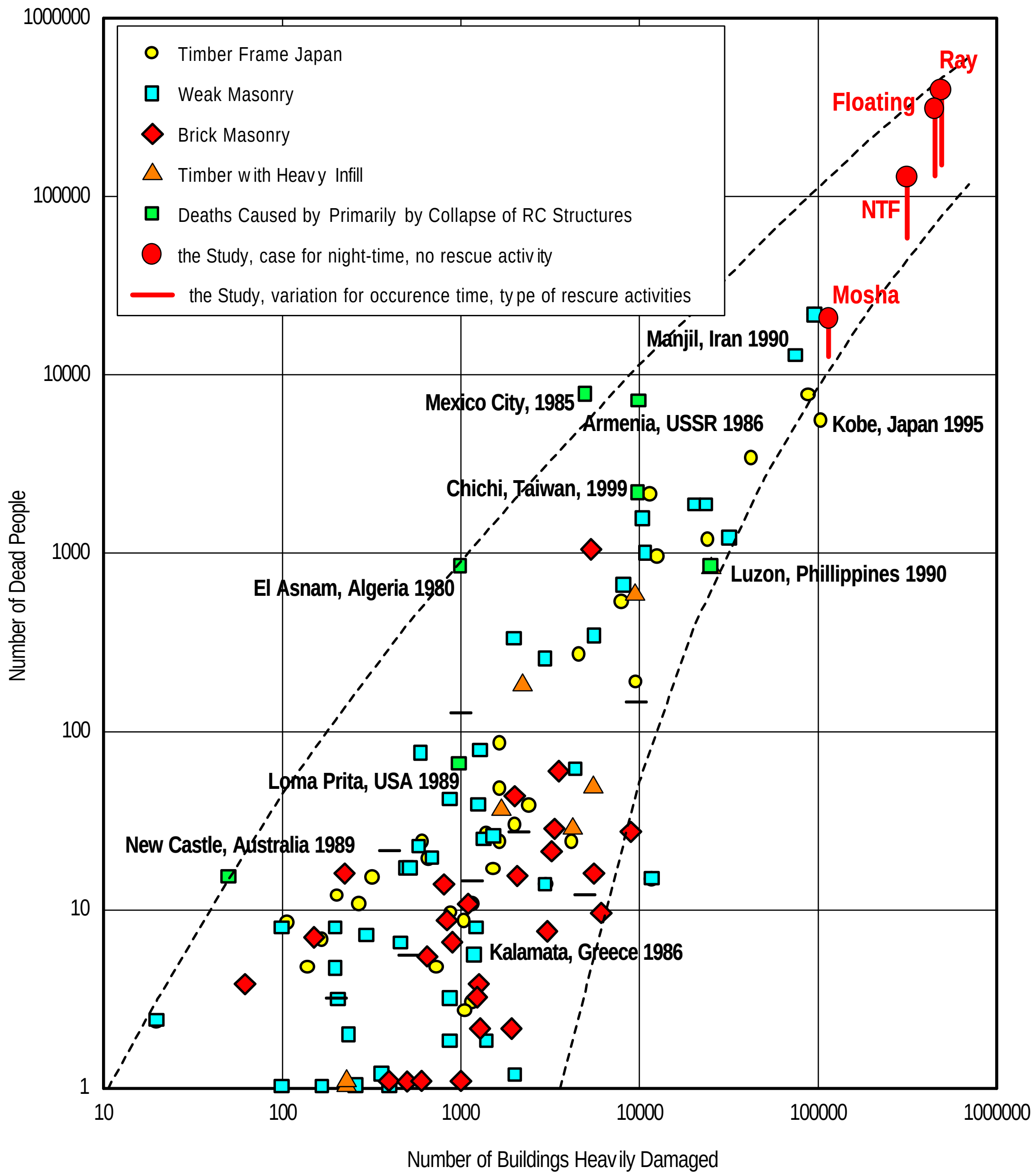

Figure 4.2.22 Relationship between Total Casualty Figures and Total Building Damage Statistics (added to Coburn and Spence 1992)

References for section 4.2

Coburn,A.W., R.J.S. Spence, and A. Pomonis, 1992, Factors Determining Human Casualty Levels in Earthquakes: Mortality Prediction in Building Collapse, Proc. 10th. WCEE.

Coburn, A.W. and R.J.S. Spence, 1992, Earthquake Protection, John Wiley.

4.3. Bridges

The method adopted for the damage analysis of bridges is different from that of buildings. The reasons are as follows:

- The body that manages the construction of bridges is a public enterprise and the structures are designed by concepts which are comparatively uniform.
- There are very few possibilities of low quality construction, because there is a strict inspection of the constructed structures.
- The basic factors that affect damage analysis are the type of structure, the dimension of the structure and the intensity of the earthquake motion.
- The differences in structural details do not always affect the analysis results.

Considering the above, the ‘ point evaluation procedure’ , i.e. the multi-dimensional quantification theory one was adopted in this Study. The input data in this procedure is very practical. An engineer is able to obtain almost all of the input data by going to the bridge site and observing the structure. The results obtained from the ‘ point evaluation procedure’ describe what amount of damage may be expected in infrastructures at the time of an earthquake. Moreover, the results of the analysis indicate the priority with which the facilities should be strengthened. The higher quality of the input data is available, the more the survey and evaluation results will be accurate. It is crucial that once some bridges are judged to collapse then a detailed seismic analysis should be undertaken as precise as the original design. A flowchart of the damage estimation for bridges is shown in Figure 4.3.1

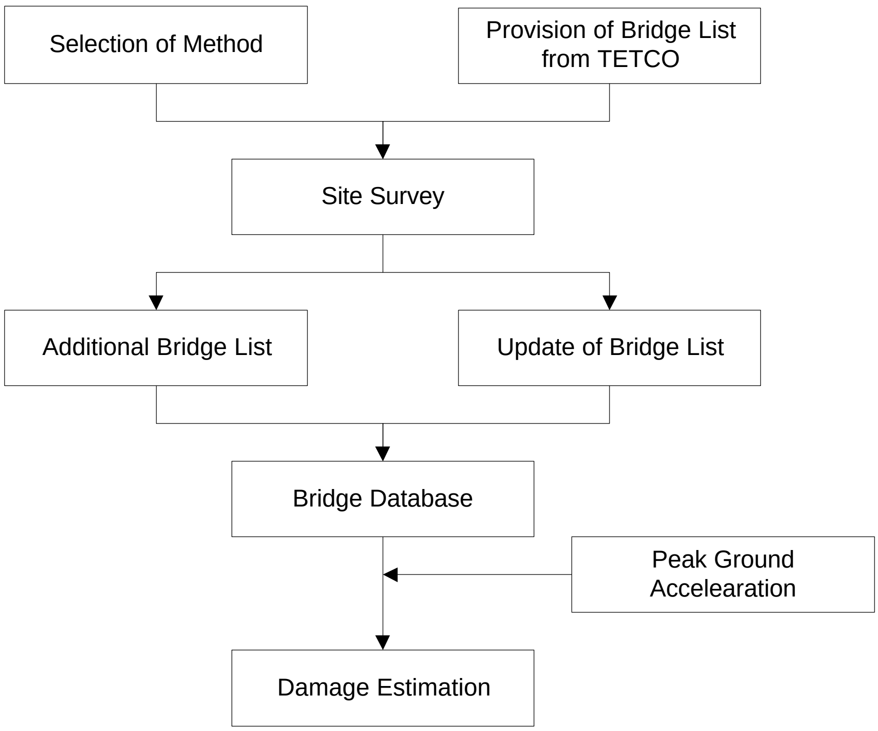

Figure 4.3.1 Flowchart of Damage Estimation for Bridges

4.3.1. Method of Damage Estimation

The seismic damage possibility judgement of the bridge is based on the method proposed by Tsuneo Katayama. The method (Disaster Prevention Council of the Tokyo Metropolitan Area (1978)) is widely used in Japan for practical purpose.

Detailed procedures are explained in Appendix. The following evaluation items are taken into consideration:

- Ground type
- Liquefaction
- Girder type
- Number of individual girders
- Bearing
- Minimum bridge seat width
- Maximum height of abutment and pier
- Earthquake intensity scale
- Foundation type
- Material of abutment and pier

Result of analysis is expressed as a total score. Judgement of stability of bridges is defined as follows:

- Total score 26 and above: collapsed
- Total score below 26: stable

This criteria has some problems in the cases where relatively high total scores, but still less than 26, are obtained, because the judgement is based not upon a structural analysis, but solely on the visual inspection of bridges. Therefore, the following criteria were introduced in the Study.

- Total score 26 and over: ‘collapsed’
- Total score 20 to 26: ‘unstable’
- Total score below 20: ‘stable’

4.3.2. Inventory Database Setup

For the analysis of bridge stability, detailed data of 160 bridges were provided by TETCO. The Study Team investigated most of the bridges and selected the bridges within the Study Area. Further, the Study Team found 79 bridges that were not listed by TETCO. These structures were investigated and integrated into the new bridge database, and 168 bridges were analysed for stability against earthquakes. Details are shown in Table 4.3.1.

Table 4.3.1 Number and Types of Bridges in Damage Analysis

Type of Bridge	Number of bridges	Within the Study Area and Location Identified (to be calculated)
Road Bridges (TETCO)	56	50
Railroad Bridges (TETCO)	51	0
Metro Bridges (TETCO)	53	39
JICA Study Team identified	79	79
Road-Road		50
Road-Metro, Railways		16
Road-River		11
Metro, Railways-River		2
Total	239	168

The following characteristics are observed when the bridges in Tehran are compared to bridges in other countries:

- Bridges that go across rivers are few. Most of the road structures are flyovers.
- Most of the road structures have been recently constructed. Therefore, they are designed with comparatively new concepts.
- Most of the bearings on piers/abutments are made of neoprene. Those are designed based upon the concept that the fixed and moving bearings are not distinguishable.

  Note: Moving bearings are bearings where the horizontal relative displacement of the bridge's axial direction is permitted, and fixed bearings are bearings where the horizontal relative displacement of the bridge's axial direction is restrained.)
- The number of spans is usually 2 to 4. A few multi-spanned continuous bridges exist.
- There are several temporary purpose bridges in the centre of the Tehran. Steel piers are used in these bridges.

The following are characteristics from the point of view of the design condition:

- It is considered that the bridges constructed after 1990 when the seismic criterion was established have a comparatively uniform earthquake resistance. However, it is considered that the earthquake resistance of the bridges that were built before 1990 is not uniform. These bridges were designed using standards of various foreign countries.
- Some bridges of uniform standard design exist also, and they may have a uniform quality.
- The construction quality of bridges is much higher compared to the construction quality of residential buildings.

4.3.3. Damage Estimation

The results of the damage estimation for the bridges are shown in Figure 4.3.2 to Figure 4.3.5. A list of bridges judged as 'collapsed' or 'unstable' is shown in Table 4.3.2.

Table 4.3.2 Results of Damage Analysis for Bridges

CODE	TETCO Crossing No	Bridge Name	Road 1	Road 2	Score				Judgment			
					Ray	North Tehran	Mosha	Floating	Ray	North Tehran	Mosha	Floating
101891	189	Nasr	Chamran	Jalal-Ale-Ahmad	23.8	23.8	14.0	23.8	U	U	s	U
102551	12/255	17 Shahrivar	Ahang	17 Shahrivar	21.2	15.0	8.8	21.2	U	s	s	U
102791	15/279	Fadaeian Eslam	Besat	Fadaeian Eslam	22.7	16.1	9.5	22.7	U	s	s	U
104731	473	Hafez	Hafez	Talaghani	33.7	23.8	14.0	23.8	C	U	s	U
104741	474	Hafez	Jomhury	Hafez	33.7	23.8	14.0	23.8	C	U	s	U
104751	475	Karim-Khan	Karim-Khan	Gharany	33.7	23.8	14.0	23.8	C	U	s	U
104761	476	Enghelab	Enghelab	Hafez	33.7	23.8	14.0	23.8	C	U	s	U
104771	477	Saadi	Saadi	Ekbatan	33.7	23.8	14.0	23.8	C	U	s	U
104781	478	Sepah	Sepah	Enghelab	23.8	23.8	14.0	23.8	U	U	s	U
202961	296	Azadegan - Tondguyan	Azadegan	Tondguyan	26.7	18.9	11.1	18.9	C	s	s	s
210081	-	Navab –Helal Ahmar	Navab	Helal Ahmar	24.9	17.7	10.4	24.9	U	s	s	U

C	Collapsed
U	Unstable
s	Stable

The results are classified into 3 types as follows:

- Score 26 and over: 'collapsed' (indicated by red mark)
- Score 20 to 26: 'unstable' (indicated by yellow mark)
- Score below 20: 'stable' (indicated by blue mark)

Compared to residential building damage, the number and damage ratio of bridges is low. Bridges are made for public purposes; therefore, detailed designs are usually applied and the construction quality is relatively high. The same kind of phenomenon is observed in other countries as well.

The instance of damage is small; however, the social influence is very high. Damaged bridges lose their function as roads after an earthquake. That leads to a very serious situation for rescue and restoration efforts as well as for the traffic system. The traffic flow is controlled more by flyovers than by signal systems at major crossings. Therefore, once flyovers collapse then the disruption in traffic is doubled, because not only is the upper road unavailable but the lower road becomes unavailable as well.

The bridges judged as 'collapsed' are almost all limited to temporary purposes. Their piers are made with steel. However, not all of the temporary bridges which have steel piers are to be rated 'collapsed'. The bridges, that are judged as 'unstable', require attention, because seismic stability is evaluated only from information obtained by the visual inspection of the bridges. Quantitative investigations are required for these bridges. This should include detailed structural calculations and an investigation of the reinforcement and the thickness of the steel material, etc.

The characteristics of problems observed in bridges are as follows:

- In piers made with reinforced concrete, the hoop is not considered to be adequate and shear failure can easily occur.
- In piers made with steel, the density of the bulkhead is not sufficient and, therefore, the possibility of local buckling exists.

The characteristics of ‘ collapsed’ bridges are as follows:

- 104731 Hafez - Talaghani
- 104741 Jomhury - Hafez
- 104751 Karim-Khan - Gharany
- 104761 Enghelab - Hafez
- 104771 Saadi - Ekbatan

These 5 bridges with steel piers were constructed for temporary purposes.

- 202961 Azadegan - Tondguyan

The peak ground acceleration reaches 460 gal in the case of Ray Fault Model. This bridge was constructed very recently. It was observed that the girders were not connected tightly, and it is considered that these girders are interfering with and striking against one another. Therefore, ‘ girder type’ was categorised as ‘ 2 or more spans’ and ‘ simple’ in the damage estimation by the Study Team.

If the detailed structure is identified then there is a possibility that this judgement may change.

The characteristics of ‘ unstable’ bridges are as follows:

- 104781 Sepah - Enghlab
- 101891 Chamron - Jalal-Ale-Ahmad
- 102551 Ahang - 17 Shahrivar

These 3 bridges with steel piers were constructed for temporary purposes.

- 102791 Besat - Fadaeian Eslam

This bridge was constructed recently. Piers are considered to be reinforced or pre-cast concrete. ‘ Girder type’ is categorised as ‘ 2 or more spans’ and ‘ more than 1 continuous’ in the TETCO list. The bridge is long;herefore, it was considered that temperature changes would lead to serious expansion of girders and a multi-span structure was used to avoid the expansions. It is considered that these girders are interfering with and striking against one another.

Figure 4.3.2

Damage of Bridges (Ray Fault model)