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Special structures, damage report of the Manjil earthquake on June 21, 1990

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ABSTRACT: Structural characteristics damages of special structures (Dams, Bridges, Silos, Cement factories, Power plants, Elevated water Tanks, Tunnels, Buried pipelines, Maritime structures, etc.) due to the 1990 Iranian (Manjil) Earthquake are discussed by using about 100 Slides. This paper summarizes the structural damages in Gilan province where the role of the soil conditions due to Caspian sea was dominant. These observations were made during four site visits by the author in June and July 1990.

1 Introduction

The Manjil Earthquake occurred on 21 June 1990 at about 30 minute past the midnight and was strongly felt in six provinces of northern Iran. The magnitude of the earthquake was Ms=7.3 - 7.7 at the depth of about 20 -30 km. The maximum intensity in Manjil is estimated to be X (MSK) and in Lowshan IX (MSK). Maximum recorded peak ground acceleration was about 65%g obtained on the instrument installed in Abbar (near to the causative fault).

In general, the damage in the remaining districts of Gilan Province was twice that in Zanjan province. This is not only due to the much higher population densities in Gilan, it may also be due to Caspian sea coast. Town like Rasht at distance of 60 km northeast from the causative fault and sited on the coastal plain, suffered significant damage with some buildings collapses (Mainly tall, flexible structures).By comparison the towns in the mountain valleys to the south, for example Zanjan at a similar distance of 65 km from the epicentre escaped very lightly with only repairable damage reported. This suggests that in the softer soils to the north east there was significant amplification of ground motion and probably increased long period content in the response spectrum, compared with a more rapid attenuation through the harder surface geology of the Zanjan mountains.

The Manjil earthquake not only killed about 40000 people and destroyed large number of houses and buildings , it caused severely damages in transportation facilities and lifeline structures.

2 Large Sefidrud (Manjil) dam

This buttress dam is located 3km northwest of Manjil, so its location coincided with the site where the earthquake had the maximum intensity. The height of the dam is 106m and at the time of the earthquake the reservoir was almost full. Generally the dam kept its structural integrity and its own global. One of the middle buttress support has been suffered a little subsidence and some horizontal and diagonal cracks developed at the top of some buttress and at the same level, some longitudinal cracks due to the poor resis-

Figure 1. Buttress Sefidrud Dam built near fault.Experienced cracking at the interface of crown and tops also longitudinal crack has occurred.

tance appeared. Non monotonous settlement of two side dam supports was the main reason for these cracks.

.3 Manjil Tunnel

Generally, damage to most tunnels has been moderate or slight. In most cases damage is limited to the entrance due to the reflection of earthquake waves. Some tunnel entrances have been damaged due to rockfalls or soil instability. A particular example of a damaged tunnel inside lining was observed in the case of the tunnel near Manjil dam. This damage seems to be the result of relative ground movements due to the activated fault passing through the tunnel and continuing across the river canyon close to the downstream face of the Manjil dam.

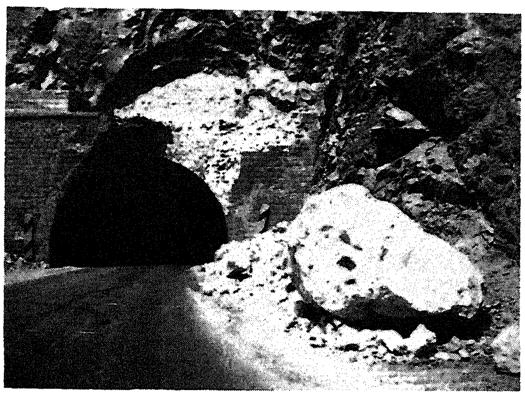

Figure 2. Cracks and partial collapse of the concrete and stone masonry facing in Manjil Tunnel entrance.

4 Long Bala - Bala bridge

This bridge (L =780 m) with prestressed girders, between Lowshan and Manjil has experienced permanent soil deformations of 5 to 8^{cm} around almost the all piers which clearly indicate the lateral tilt of the bridge superstructure. Certain horizontal cracks of the middle piers have been also observed. Damage to bridge structures was most commonly observed near to the end pier supports (as settlements of the soil), in areas in both support concrete wings, and in the approach ground embankments. Due to the much larger superstructures mass and imposed greater inertial forces, the supports, as well as expansion joints have experienced relative movements in longitudinal , tran - versal or in some combined directions depending on the global orientation of the bridge relative to the imposed dominant direction of earthquake ground shaking. Steel bridges appeared to suffer much smaller relative movements of the superstructure than R.C. bridge in the area (Rudbar steel bridge).

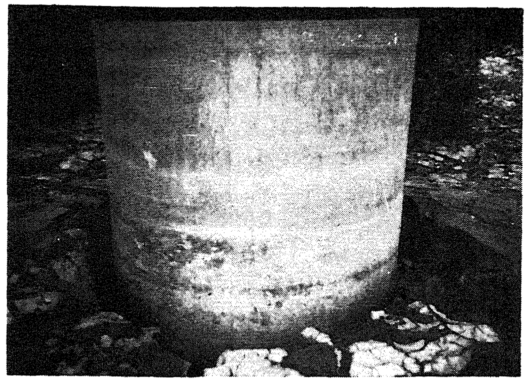

Figure 3. visible lateral permanent deformations of Bala - Bala bridge piers due to the liquefaction phenomena.

5 Lowshan power plant

In general, the electrical power generation system and supply networks , including power plants, transformer stations, electricity distribution lines have sustained moderate damage and only in a few cases has heavy damage been recorded. One such case was the power plant in Lowshan which has been heavily damaged. One kind of damage has been produced by malfunctioning of the transformers rail supports caused by ground motion.

Torsion and settlement of one of the columns which had supported power plant generator produced severe damage and caused the suspension of electricity production.

Most shock absorbers on the transformer rails were broken and the transformer resting on such support, have experienced strong seismic shocks and sustained heavy internal damage.

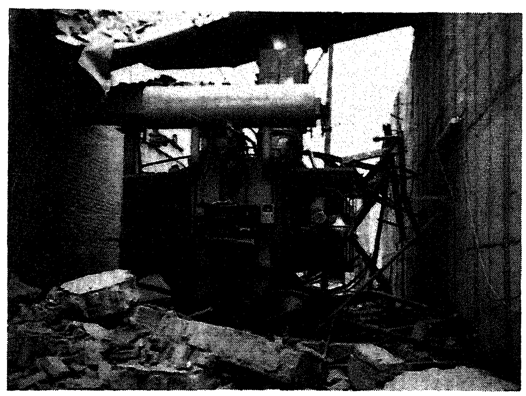

Figure 4. Lowshan power plant transformer damage due to the partial collapses of last storey walls

6 Saravan Reinforced Concrete Silo

The Manjil earthquake was the first strong seismic action that confronted the Saravan 120 000 ton R.C. silo. Due to the relatively long epicentral distance of about 40 km, the fundamental vibration period of the ground at the moments of highest intensity was large. This lead to more unfavourable effects for flexible structures. The Saravan cereal silo was not amongst the most unfavourable affected buildings owing to its massive character. Under these circumstances and benefitting from a generally robust structural setting, the silo practically had an elastic dynamic response whereas the multistory and other high rise buildings in Rasht displayed considerable excursions into the inelastic range.

Generally structural damage to this silo has been moderate. Some cracks in the structural elements of the tower were recorded. The big electric control box in the elevator tower has been overturned due to the insufficient guy. The cell groups structures remained unaffected and the only part that was in some cases damaged was the connection of equipments with the roofstory structure. The flexible structure of the heavy precast R.C. roof placed on top of a rigid building displayed an amplified dynamic response, which increased considerably the lateral seismic forces at the roof level.

Some slightly damages have been observed in the cells - Tower corridor due to the different rigidity (rigid cells groups and flexible Tower).

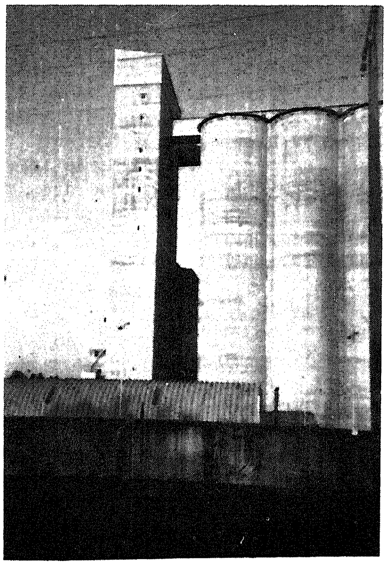

Figure 5. RC 120 000 tons silo damages in the cells - Tower corridor due to the different rigidity.

7 Rasht Elevated Water Towers

The elevated water tanks in the affected area can be basically divided into two categories according to structural material. Smaller capacity tanks are mainly steel while larger elevated water tanks have been constructed from reinforced concrete.

Almost all steel water tanks behaved very well and only light damage to the structural systems have been observed. In some cases, the extent of the observed damage was limited to buckling and snappling of the structural bracing.

However, the water tanks constructed of R.C. behaved slightly differently. A specific example is the collapsed R.C. elevated water tank in Rasht which was built some 20 years ago. The capacity of this water tower was approximately 15.00 m^3 , and it consisted of a R.C. shaft, 6m in diameter and 30cm thick, and a prestressed concrete tank 10.3 m high, wiht its top 46.5 m from the ground. At the time of the earthquake it contained about 1000 m^3 of water.

Two similar but larger R.C. water towers in Rasht which had just been completed prior to the earthquake were both empty. Both of these structures have suffered very slight damage, and in one case, cracks have developed around the shaft at a height of about 3 m from the tower bottom.

Since the collapsed R.C. water tower was in use and contained significant amount of water in the time of the earthquake, its behaviour can be regarded as dynamic response of long period structure and oscillation and impact mode effects. Relatively long epicentral distance of about 50 km, high response amplification is probable inherent with a resonant effect resulting consequently in the total collapse of this structure.

Figure 6. Total collapse of elevated water tank 1500 m^3 in Rasht

8 Lowshan cement factory

This new cement factory (2000 ton) which had been completed several months prior to the earthquake, generally has sustained moderate damage but in some parts has heavy damage been recorded.One of these part was the Knapping - hammer building (R.C. frame with masonry infill) where its control room roof has been completely collapsed due to the very poor connections. A large number of the separation of the wall brick infill and severe cracks in the walls have been observed. Vertical displacement (5-10 cm) in a large part of this factory has been recorded.

Comparing with the other parts of this factory, the behaviour of its silo has been relatively satisfactory. Although one crane which had been used for construction of this silo, has completely overtuned.

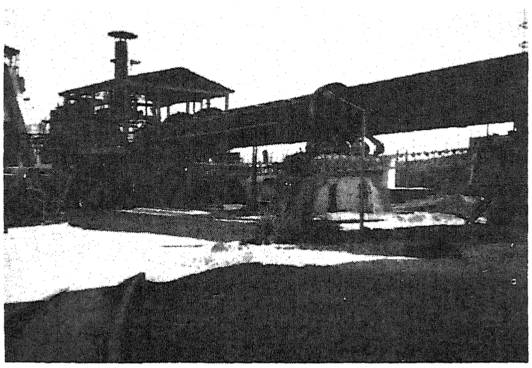

Figure 7. Settlement of the Lowshan cement factory kiln's foundation

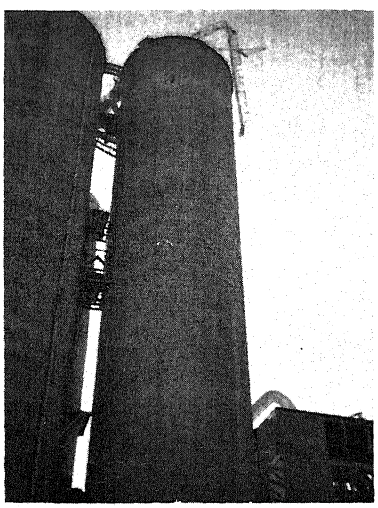

Figure 8. Overturned crane in Lowshan cement factory

9 Retaining walls, Embankments and Cuttings

A large number of highway engineering structures such as retaining walls, embankments, cuttings have been severely damaged. Damage was most severe in mountainous regions. The observed damage degree of these structures was in close correlation with epicentral distance, slop of the ground surface and largely in correlation with the conditions and dynamic properties of the local soil.

A significant number of retaining walls near the end supports of bridges have sustained permanent deformations due to the increased total effective pressure under the severe ground shaking. The similar types of damage and even total collapses also have occurred in many constructed retaining walls along the roadways passing through mountainous regions with relatively steep surface slopes.

The embankments and cuttings along the roadways have been also exposed to a variety of damage and failure modes, such as large permanent horizontal and vertical deformations, cracks parallel or normal to the road surface, extensive settlements, and complete failures of certain road sections, due to the activated landslides.

10 Roads and Road Structures

The extent and types of damage to roads and highway Structures largely dependent on the position of the road section. Road sections passing through wide and flat areas mainly have been damaged due to the ground settlements as a result of liquefaction or other types of dynamic soil instability. Contrary, the road sections passing through steep hilly and mountainous regions have been much severely damaged due to the local and global instability of the slopes as well as due to the other relative movements producing transversal areas with different wideness. Very frequent damages of roads in mountainous regions have been produced due to the ground and rock slope failures which resulted in complete closure of the roadways and severe transportation difficulties during the most urgent rescue operations immediately after the earthquake.

11 Pipe water supply Network

Earthquake damage to water supply networks and pumping stations located in the mountainous and lowland areas was widespread.

In mountainous areas pipe reptures have been mainly caused by large ground deformations as a result of extensive landslides, wide ground cracks, and settlements of uncompacted soil deposits. The damage to the pipe water supply networks in the lowland regions have been the result mainly of

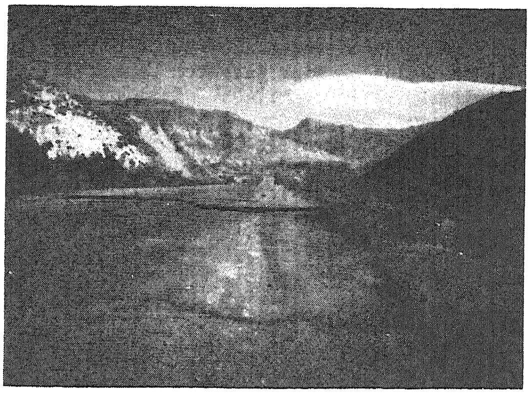

Figure 9. Road's Pavement transversal displacement

liquefaction phenomena resulting in severe dynamic soil instability and large permanent vertical deformations of the ground.

12 Maritime Structures

Two main ports (Anzali and Nowshahr) were located in the north part of the fault up to the coast of the Caspian sea.

In spite of the long epicentral distance, the breakwaters in these ports have suffered low levels of damage. The damages produced to the old breakwater of Anzli port were more severe. Major cracks and displacements in its top were recorded. The Nowshahr harbour's breakwater (composite type) and its sheet pile Quaywall had a good behaviour and only some little swells occurred in some parts of its breakwater, due to the non monotonous displacement between the solid (concrete) and ductil (rubble) parts.

13 Sangar Control Dame

This trap's control dam which has been located about 15 Km from Caspian sea coast and 25 Km from causative fault, contained 13 traps. Landslide in the area of dam and pit creation near it have been observed.

The mechanical equipments of some traps such as retaining cables of equilibrum weight beams for open and closing of traps have been heavily damaged, caused by settlement of the supports due to the liquefaction phenomena. Non ductile connections between the equipments and their supports have been aggravated this kind of damage

14 Buried pipline

During the Manjil Earthquake, buried pipline systems have slightly been damaged. Damage to pipe body(breakage, bursting, cracking and thrusting) to the extension in the

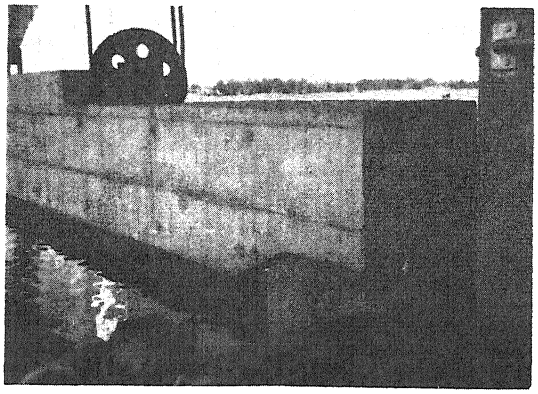

Figure 10. Collapse of the equilibrium Trap's beam due to the defects of mechanical and installed equipments in Sangar Control Dam.

longitudinal direction and damage to joint (breakage, pulout and looseness) under a combination of extension and rotation have been observed.

Generally the damages at joints were caused at liquefied sites near the boundary between the liquefied and non - liquefied sites. The causes of these pipe damages could be explained in terms of variable ground movements due to sharp change of the ground characteristics and buoyancy effect at the liquefied site. Some damages were also caused at sites where permanent ground displacement has been occurred.

15 Other Lifeline Structures

The damages to others lifeline structures can be summarized as follow:
Soil liquefaction caused extensive damages in the relatively large area northeast from the epicentre. Loose fine water saturated sandy soil of marine and river deposits liquefied resulting in occurrence of sandboils, total and differential settlements of the building and streets and disposition of irrigation channels.

The steel cooling towers and the fuel circular resevoirs in Lowshan power plant appears to have performed very well and no damage could be observed.

Telecommunication facilities including telephone lines, relays, etc. have suffered low levels of damage.

The destructive effect of the earthquake includes several important industrial facilities in the region, including two leather processing factories, one shoe manufacturing factory and various other smaller industrial facilities. The sturctural systems of these damaged factories were well designed and constructed steel portal frames with appropriate geometry. Only minor damage has been caused to the structure itself, in buckling of some of the bracings, torsion of the columns and some permanent lateral displacements.

Rudbar hospital (Reinforced concrete) has suffered heavily damages due to the non aseismic design, weak joints, bad quality of concrete and poor workmanship.

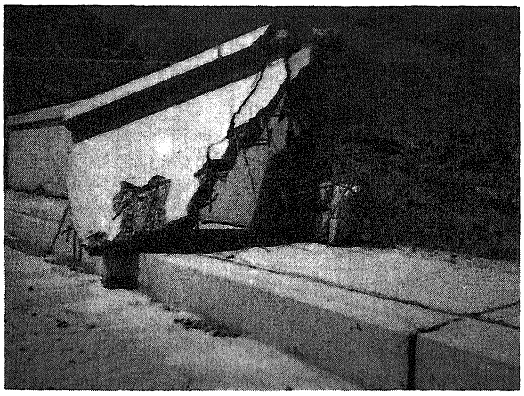

Figure 11. Damage of the parapet walls on the Sefidrud dam's crown.

16 Conclusion

In general , regarding the damage to lifeline structures due to the 1990 Manjil Earthquake, we can note that almost all damages appears to be the result of insufficient attention to aseismic design, soil condition and soil-structure interaction, suitable construction and structure's maintenace. Certainly, the behaviour of all structural elements which had correctly been designed, were Satisfactory.

17 Acknowledgements

The technical review and remarks , all slides and photographs were prepared during author's site visits which were organized by University of Tehran and Ports and Shipping Organization.

The author would like to thank the authority of University of Tehran, Ports and Shipping organization, Gilan State, National Iranian Gas Society, Ministry of Energy, Ministry of Industry, Ministry of Jihad (Construction).

REFERENCES

Bargi, KH.1991. Observation of Manjil Earthquake. National Iranian Gas Society Seminar.

Bargi, KH. 1990. Maritime Structures, Damages Report of the Manjil Earthquake. Ports and Shipping Organization.

Bargi, KH. & Nourzad. A. 1991. Manjil Earthquake effects on Lifeline Structues. Gilan University Conference.

Moinfar, A.A. & Naderzadeh, A. 1990. The Manjil, Iran Earthquake of 20 June 1990. Building and Housing Research Center.

Coburn, A.W., Petrovski, J. , Ristic, D., Armillas, I. & Biering, N. 1990. Technical Review of the Impact of the Earthquake of 21 June 1990 in the provinces of GILAN and ZANJAN. UNDP Report.