LESSONS FROM NIIGATA EARTHQUAKE

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SYNOPSIS

This paper enumerates some of the lessons we may learn from the damage done by an earthquake which struck the Japanese city of Niigata on 16-6-1964. The earthquake damage was characterised by its close relationship with the ground conditions, Tsunami and outbreak of fire. A study of damage pattern to the civil engineering structures reveals instructive information which can be helpful in the future planning, design and construction of earthquake resistant structures in similar areas. Some shortcomings in design and construction of the existing building structures have been pointed out and remedies suggested. The writer visited Niigata in Dec. 1964 and collected some material for this article.

INTRODUCTION

On June 16, 1964 at 1.02 p.m. Niigata a city of about 290,000 persons and Japan's largest petroleum and natural gas producing centre, situated on the Japans ea side 150 km from Tokyo was struck by an earthquake. It has a magnitude of 7.5 on the richter scale, focus 40 km below the earth surface; epicentre 70 km from Niigata and maximum acceleration of 0·16g as recorded at Niigata. This earthquake lasting only for 20 seconds claimed 15 lives, destroyed a large number of buildings and other structures, and caused damage to property in the region of 800 million dollars. The energy released by this earthquake is estimated to be equivalent to 500 bombs of the type which had destroyed Hiroshima

Niigata city is located at the edge of a low lying coastal plain on both sides of Shinano River, and the damaged zone mainly consists of loose uniform sand of fine and medium size, and in the wake of the earthquake portions of the city areas subsided varying in settlement upto a few feet. In this area the ground water-table is also high rising to as much as one meter below the ground surface in some locations. The vibratory response of the structures to the earthquake compacted the sand expelling out water, and setting the structure along with the subsidence of the ground. Similarly the vibrations of the ground resulted in a large number of sand blows. (See Photo 1)

CONSTRUCTION ON SANDY STRATA

The transient state of the phenomena termed Liquefaction of sand reduced the bearing

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Pho o No 1 "Sand Blows" at Niigata

capacity of the soil due to increase in soil pore pressure, and consequently a number of structures sank into the ground. A group of gasoline pumps had sunk into the liquified sand under their own weight so that only the inclined tops remained visible. Thus it is seen that loose sandy soil is very susceptible to shock vibrations as compared to harder strata in the same area.

To mitigate the damage on such soils due considerations should be given for stabilisation of loose soil before starting the construction work.

FOUNDATION CONSIDERATIONS

At Niigata it has been observed that the buildings having basements comparatively suffered less damage than those without basements. This is illustrated by the tilt in some of the buildings in a group of four storeyed reinforced concrete apartments one km west of the prefectural office, where two apartments having basements suffered little tilt. Buildings having pile foundations behaved better than those without piles. For example four storeyed main railway station of Niigata was undamaged as it was founded on piers. Again, structures with both the basements and piles sustained almost no earthquake damage. The two prefectural offices consisting of four storeyed and six storeyed, and having basements as well as pile foundations did not suffer any damage even though the areas around these buildings showed settlement and distortion. Also buildings having mat foundations suffered less damage than those having individual or strip foundation.

Therefore in the planning and design of earthquake resistant structures provision for basement and pile foundation should be given adequate consideration. Photo II shows a overturned apartment exposing the bottom stones of the foundation and indicating the inadequate depth of foundation.

BRACINGS AND SYMMETRICAL LAYOUT

At Niigata it was observed that the interior of many affected buildings was distorted and walls collapsed though the roofs did not suffer any damage. Hence it is important that the main structural parts of a building such as walls, cornices, parapits, columns etc be tied to the interior frame-work and to the foundation from the lowest floor to the top floor, giving the power or resistance to the buildings as a whole.

The geometric shape of the building is also imp rtant. Structures having rectangular cross section, vibrating in a unit without interface from other structural parts withstand the shock vibration best. In the case of a building consisting of two or more irregularly shaped portions, the earthquake response of the building is different in different parts and consequently may tend to knock against each other. This is supported by the fact that at Niigata the damage to many buildings was limited to entrance canopies and connecting links.

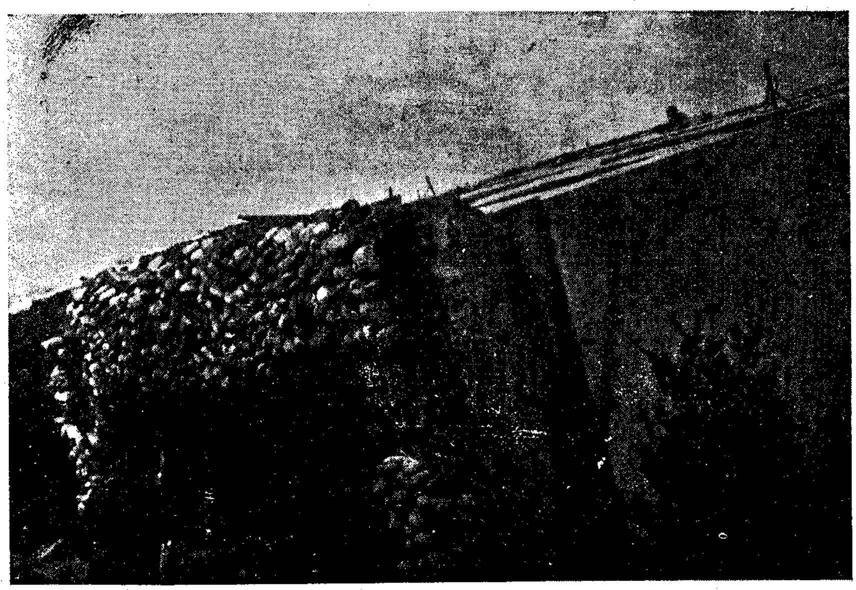

Photo No. 2 Overturned Apartment at Niigata Showing the Foundation Stones

CONSTRUCTION MATERIALS

It is not merely the apparent strength of a structure but rather its true strength in relation to its weight which controls its earthquake resistance. This may perhaps be the reason for comparatively lesser damage to lighter wooden old shrines. At Niigata in most cases it was observed that the heavier of two adjacent buildings had settled most, and the lighter buildings had inclined toward the heavier ones. Thus the buildings constructed with lighter materials are better. Mathematically the period T of vibration of a structure of weight w is given by the relation:

$$T = 2\pi \sqrt{w/gk}$$

This shows that the weight of a building affects the natural period of vibration directly.

Also earthquake resistant structure should be constructed of ductile materials that are strong and have energy absorbing qualities which can withstand dynamic forces without fracture, since stiff and brittle members cannot withstand the vibrations of a severe earthquake. At Niigata this has been demonstrated in some buildings which did not seem to suffer complete collapse as the comparatively ductile steel constituting the side walls had simply bent out. A properly designed structure built of ductile material can absorb a large amount of energy in plastic deformation and hence it is not necessary that a structure must behave elastically in the maximum designed earthquake.

The importance of providing ductility in a structure is twofold. Firstly that when the material is strained in the plastic range due to the earthquake shock the strain energy absorption is much more than that in the plastic range for the same increase of strain and consequently is a source of extra natural damping. Secondly, the failure of the structure is not sudden thus giving sufficient warning before ocmplete collapse thereby mitigating the possible loss of life and property due to an earthquake.

TSUNAMI DAMAGE

A small tidal wave hit Japan sea coastal area less than thirty minutes after the earthquake which caused backflowing of the river Shinano and flooding of the low-lying regions, causing severe damage to life and property. A stronger embankment on both sides of the river could have mitigated the loss. In some cases the onrush of the Tsunami is preceeded by a clearly visible withdrawal of seawater for a short period which may be taken as a warning by the people to rush to the higher grounds.

DESTRUCTION BY FIRE

In the wake of the earthquake fire broke out when a tank of Showa Oil Co. containing 40,000 kilo-litre crude oil blew up. Soon it spread out to more than 80 tanks containing crude and refined oil and damaged more than two hundred buildings. The fire raged for about thirty hours before it could be brought under control by dropping chemical foam bombs from the air. The cause of the fire is not definite, but the fire disaster highlighted the effect of a big earthquake on oil tanks. In this connection three points need considerations. Since the oil refinery and petrochemical plants are completely automatic in Japan it needs investigation whether the automation devices can set off the necessary emergency controls as efficiently as a trained staff before installing such systems in an area vulnerable to earthquakes. Again at Niigata near the oil tanks there were other tanks containing tetra-chloride ethyl and methonal which give poisonous gases and explosive hydrogen gas. Hence the second debatable aspect is the wisdom of locating such tanks in a factory area. Thirdly the non-availability of necessary chemicals and other fire fighting equipment and the inadequate capacity of the available protection devices to deal with the initial outbreak of fire focuses the importance of adequate and quick fire protection equipment near such places.

CONCLUSION

In conclusion it may be pointed out that the intensity of ground motion at Niigata was much less in comparison to the severity of damage to the structures. This accounts for the fact that the damage was not due to the vibrational effects of structures but due to the deformation and decrease in the bearing power of the soil. Though the structures were made sufficiently strong, proper consideration was not given to the foundation requirements, in the soil which could then liquefy due to an earthquake. The damage at Niigata brings to light the dangers inherrent in constructing Engineering structures on fills or reclaimed land. The lessons of this catastrope can well be kept in mind when plans for the construction in similar regions are drawn.

REFERENCE

Falconer, (1965), "Immediate Report on Inspection mission to Niigata City", Niigata earth Earthquake, I.I.S.S.E, Feb. 1965.