

THE FRIULI (ITALY) MAY AND SEPT. 1976 EARTHQUAKE

A BRIEF SURVEY OF THE DAMAGES

by

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Synopsis

An overview is presented of the damages caused to the principal types of constructions of the Friuli region by the sequence of shocks that lasted from May to September, 1976.

Introduction

The Friuli is a northern region of Italy of very ancient civilization, situated at the foot of the eastern Alps along the main routes for central Europe. Its greater economical and artistical period spans from the eleventh to the sixteenth century, during which the major towns were enriched with buildings and monuments. The integrity of their historical character was generally at a good level before the quake. The main shock happened on May the 6th, 1976 ($M = 6,4$), followed by more than two hundred aftershocks until a final intense shock ($M = 6,2$) occurred on September the 11th: this last was decisive in provoking collapse of many previously damaged structures. In spite of several historically recorded past earthquakes (13 of them of IX MM intensity), only a marginal part of the region was officially retained as seismic: most of the existing structures were thus not designed to resist horizontal actions. A concise account of the damages is reported below.

Residential Buildings

Three ample categories can be recognized, a synoptical table of the damages suffered by each of them in 8 major towns appearing in fig.1. Type 1 - Masonry houses, one or two stories high, built with irregular alluvional stones, having wooden floors and roofs, lacking of connections between orthogonal walls. Widely diffused in rural as well as in older parts of the towns. Most of them seriously damaged or collapsed (fig.2) .

Type 2 - Hybrid constructions, two or three stories high, partly made of reinforced concrete columns and beams, and partly of hollow brick walls. Generally of poor construction quality, damages influenced by the amount and distribution of secondary elements like internal partitions and external walls.

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Type 3 - Reinforced concrete buildings, from three to eight stories high. Degree of damage influenced both from the structural layout and the presence of non structural elements. Partially or totally free first stories caused the majority of the failures (figs 3 and 4); asymmetry of the first story columns height caused unrecoverable damage of the G section of the Gemona hospital, the main building of the region (figs 5 and 6), while asymmetry of the first floor perimetral walls caused rotation and subsequent collapse (on September shock) of the B section of the building in figs 7 and 8.

Computed resisting seismic coefficients of many damaged buildings ranged from 0,08 to 0,15.

Bridges

A highway crossing the region from Udine to Tarvisio, at the border with Austria, is under construction. The structural schemes of the bridges consist mostly of simply supported spans, made of prestressed prefabricated beams connected by cast-in-situ slabs, or of hollow multicellular decks. Prefabricated beams 33 to 40 meters long, waiting for use in stock areas were lost in great number due to overturning and reciprocal shocks (fig.9). Beams already in place over the piers were separated each other and fell down (fig.10). Damages to completed structures were mainly caused by the mobility of the decks, not sufficiently restrained by the supports. This is exemplified in fig.11 showing a hollow deck fall down after a displacement relative to the pier of more than 50 cm, and also in fig.12, showing the residual offset of a deck relative to the pier. Where concrete stoppers were provided over the piers, repeated collisions with the beams led to their destruction (fig.13). As another example of insufficient restraint, an elevated pipeline, carrying methane from Trieste to the north, fell down due to insufficient depth of the supporting saddles (fig. 14)

Monuments

In at least 100 towns the major buildings have been seriously affected: 20 bell towers and 50 churches have collapsed, and five castles are in ruins. Two hundred bell towers, 500 churches and about 30 castles suffered significant damages. Two medioeval walled towns, Venzona and Gemona were of preminent artistic value. Fig.15 shows an aerial view of Venzona after May, with the cathedral (13th century) still standing except for one bell tower; the same view appears in fig.16 after September, with the Cathedral completely destroyed. The old town center of Gemona after September is shown in fig.17 note the Town Hall in the center and the Cathedral on the far right. The first one, a 15th century building, appears in fig.18 while the second one, built in 13th century, with the bell tower dating back to 1330, is shown in fig.19.

REFERENCES

A.Parducci-F.Braga,F.Brancaleoni,R.Cavallo,A.Cipollini,M.P.Pietrangeli: Monographic issue on the Friuli earthquake. L'Industria Italiana del Cemento, Rome, July-August, 1976

DAMAGE TOWN	N I L			SMALL			GREAT			TOTAL		
	I	II	III	I	II	III	I	II	III	I	II	III
BUIA	0	20	0	5	36	50	5	20	40	90	24	10
GEMONA	0	0	13	2	28	50	15	43	10	83	29	27
FORGARIA	0	16	50	5	17	50	15	50	0	80	17	0
OSOPPO	7	17	80	7	33	20	13	33	0	73	17	0
TRASAGHIS	0	11	--	0	33	--	42	23	--	58	33	--
MAJANO	8	16	60	17	32	20	25	26	0	50	26	20
TARCENTO	17	30	25	25	10	75	33	40	0	25	20	0
SAN DANIELE	50	45	60	35	37	40	9	18	0	6	0	0

Fig.1 Damages to buildings



Fig.3 Yielding of first floor columns

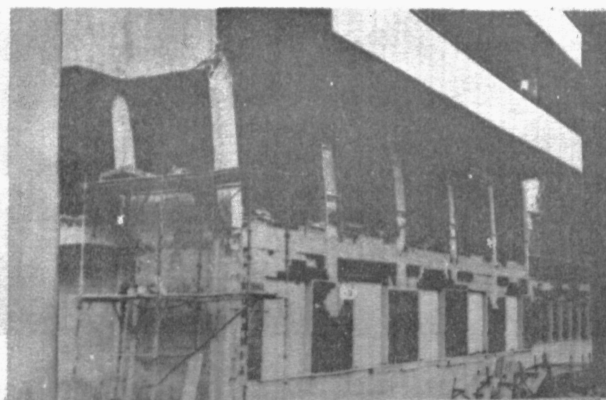


Fig.6 Gemona Hospital - G Section -
Free second floor with collapsed
columns



Fig.2 Typical masonry
house.

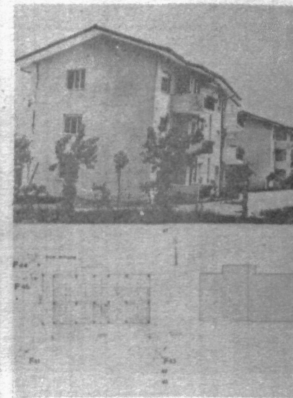


Fig.4 Base pilotis
destruction



Fig.5 Gemona Hospital



Fig.7 Seven stories building after the quake.



Fig.8 B section of building in fig.7

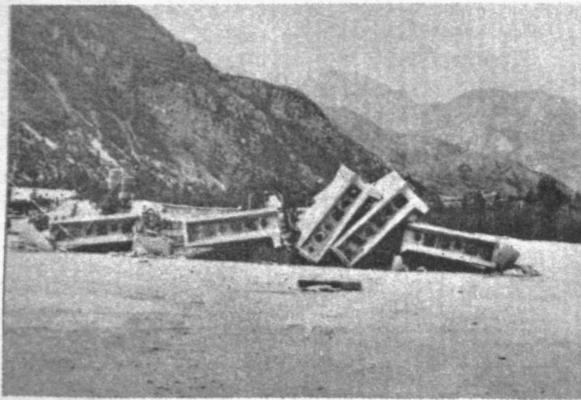


Fig. 9 Prefabricated beams waiting for use



Fig.10 Bridge deck under construction

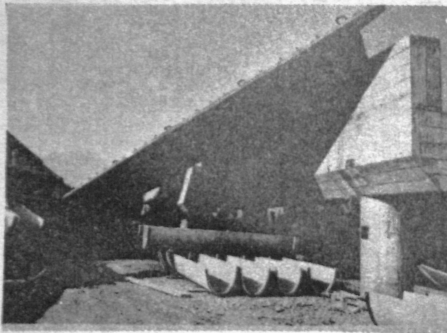


Fig.11 Collapse of a deck from the pier

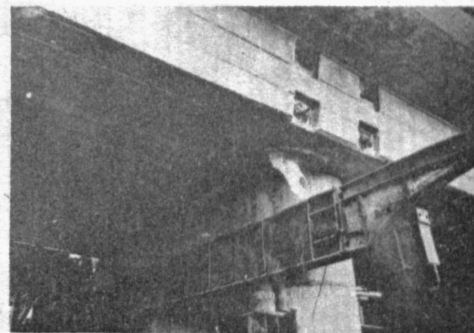


Fig. 12 Residual offset of a deck

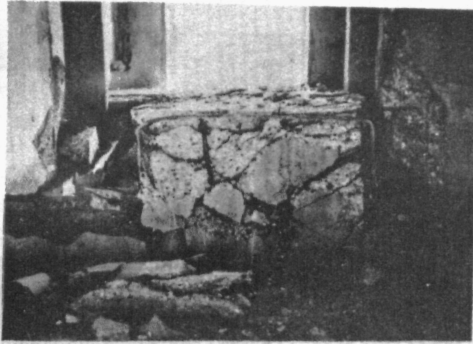


Fig.13 Destroyed concrete stoppers

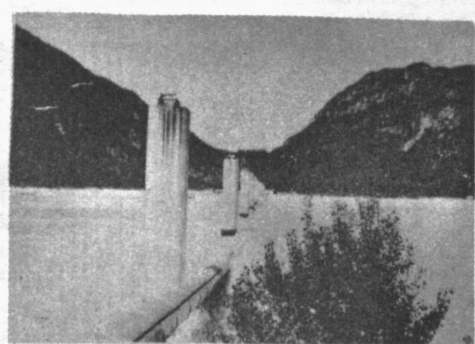


Fig.14 Metane duct fall down

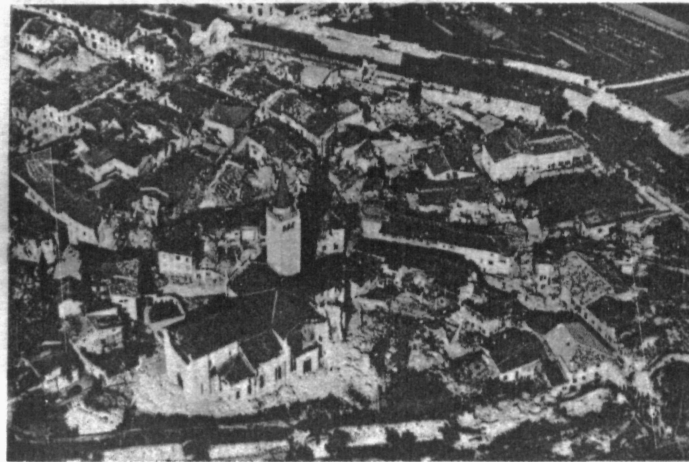


Fig.15 View of Venzone after May



Fig.16 View of Venzone after September

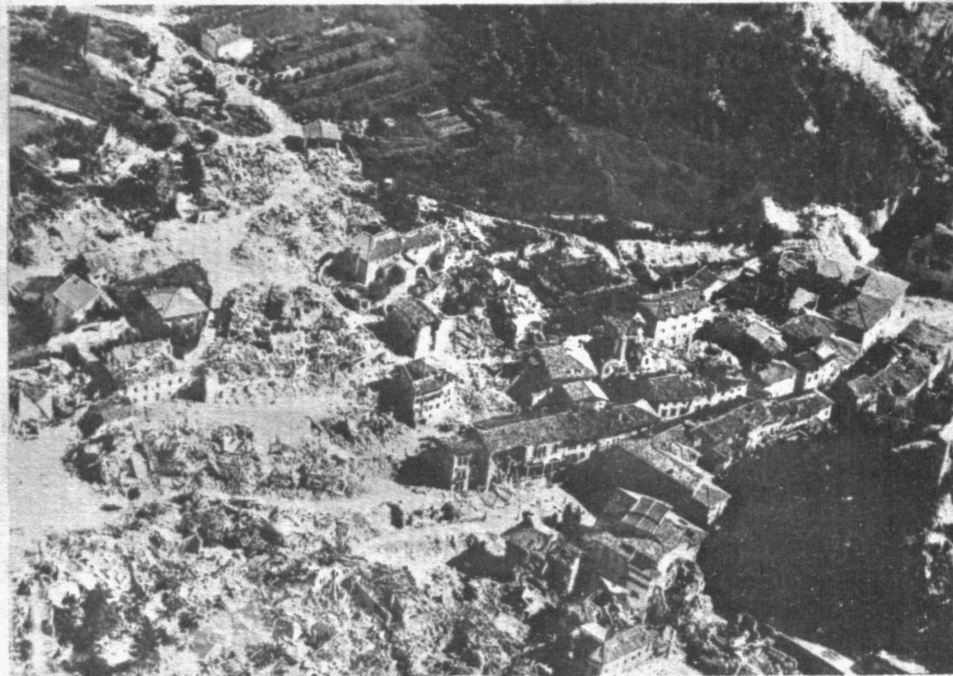


Fig.17 View of Gemona after September



Fig.18 Town Hall of Gemona
(15th cent.)

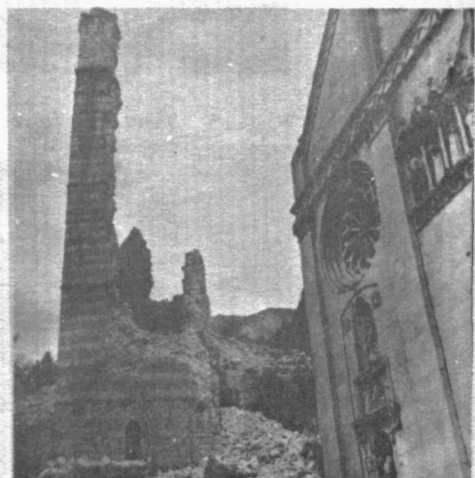


Fig.19 Gemona Cathedral (14th cent.)