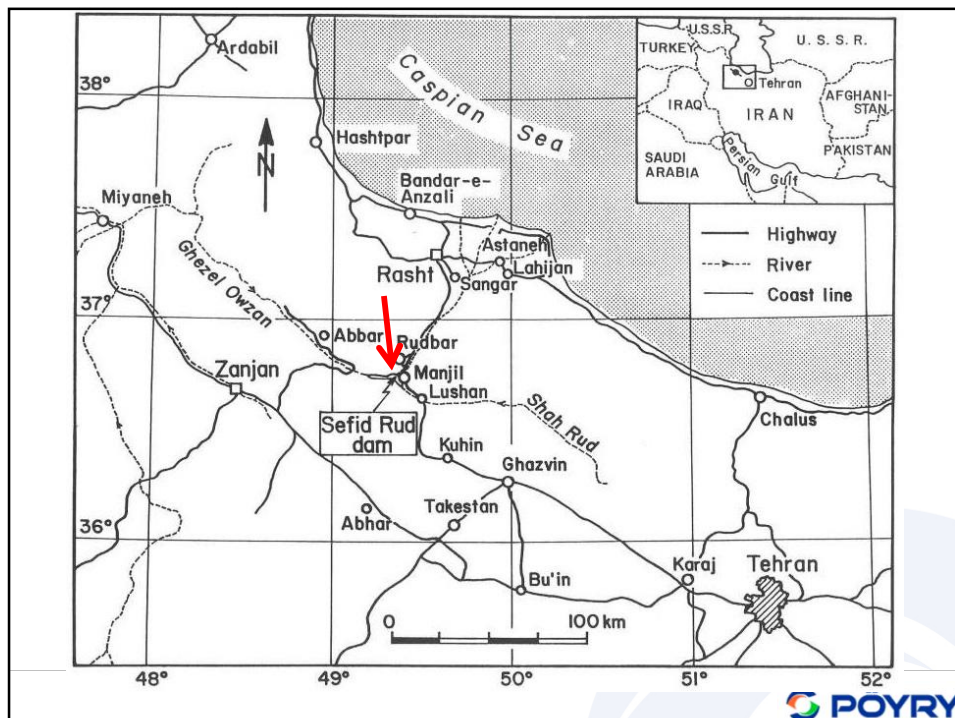


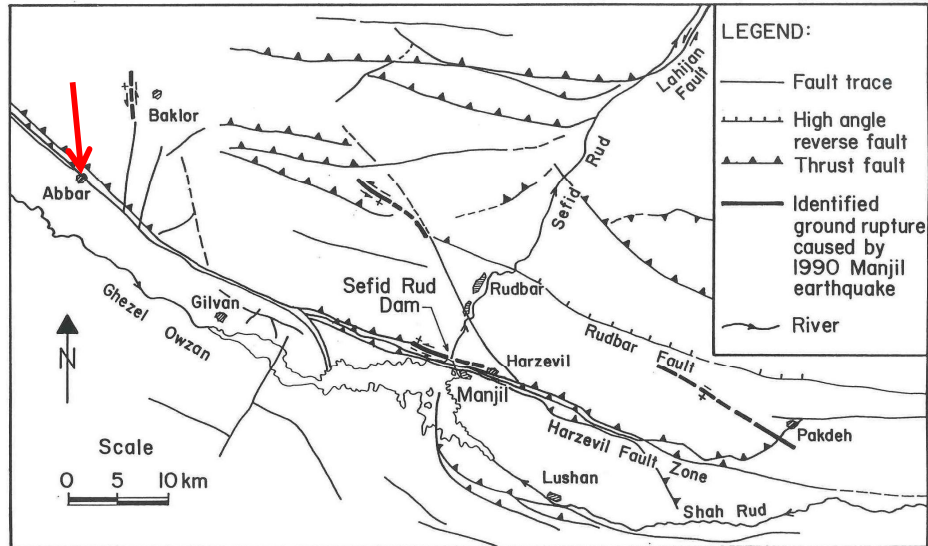
# **Damage of Sefid Rud Buttress Dam Project in Iran Caused by Magnitude 7.7 Manjil Earthquake of June 21, 1990**

**Dr. Martin Wieland**

Chairman, ICOLD Committee on Seismic Aspects of Dam Design  
**Poyry Switzerland Ltd., Zurich, Switzerland**



**Faults in dam and reservoir region; strong motion records closest to the dam are only available from Abbar**



**Access to dam through earthquake damaged villages with about 40,000 people killed by Manjil earthquake most of them close to dam site**



**Damaged village near dam site**



**Building damage close to dam site**



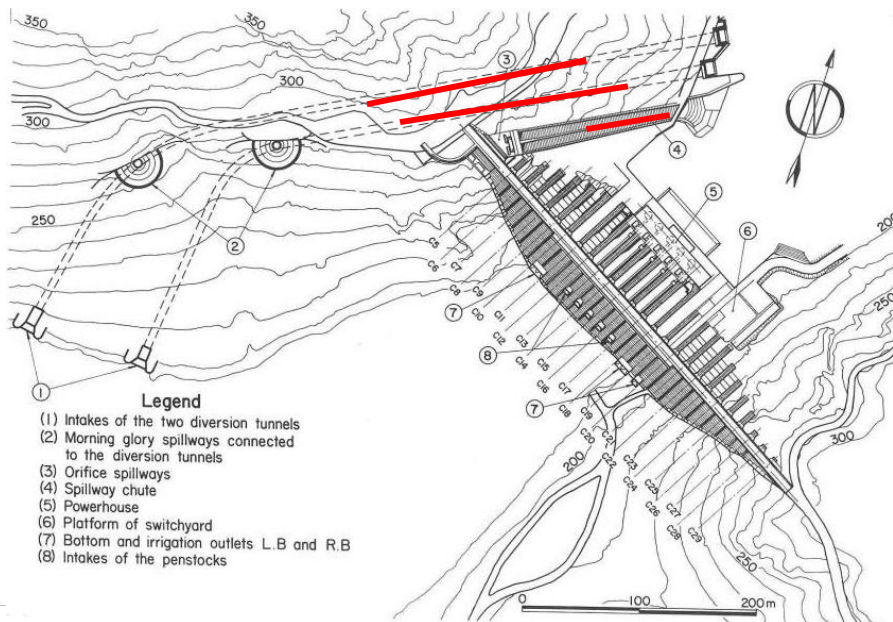


## Collapsed building at dam site



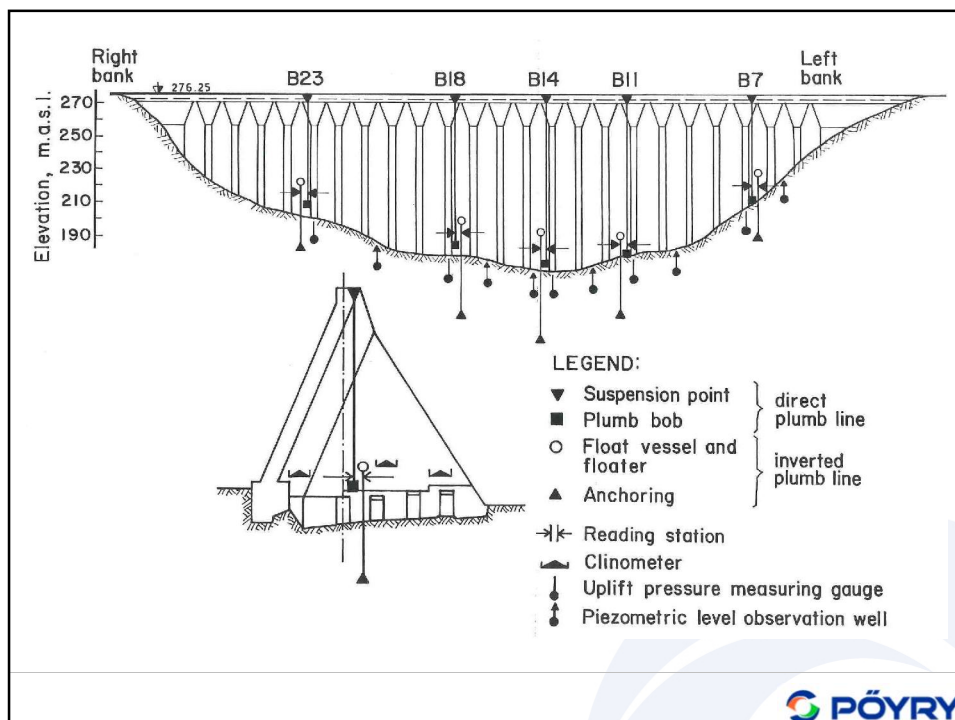
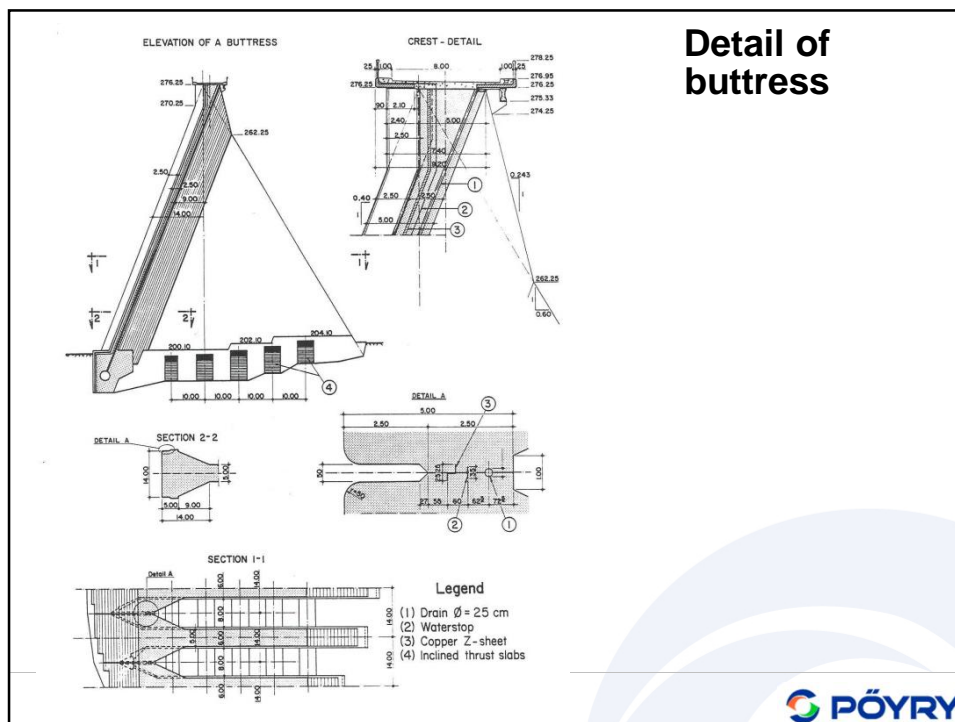
**PÖYRY**

## Dam layout with spillways



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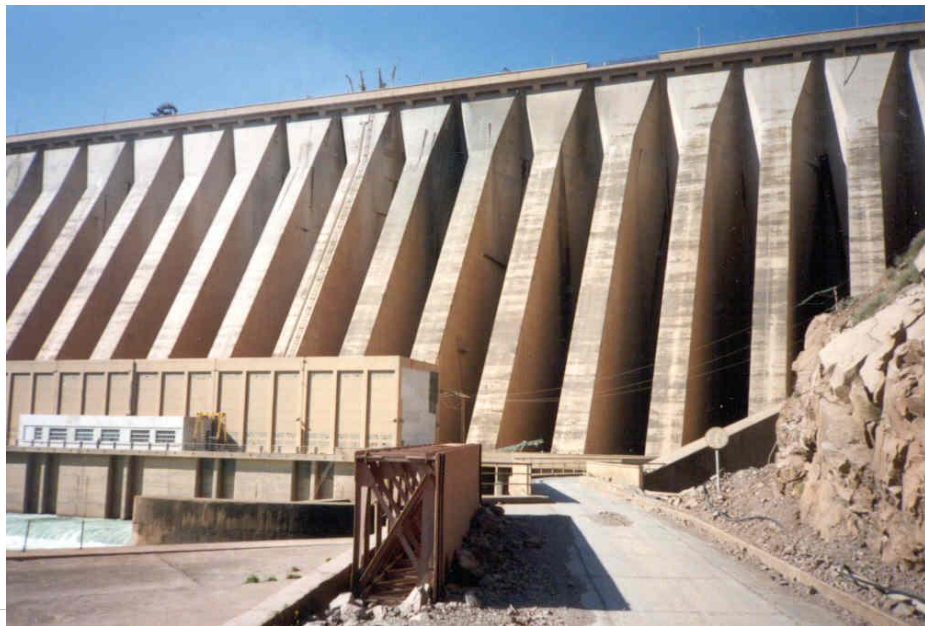




**Downstream view of 105 m high Sefid rud buttress dam: reservoir draw down by opening of irrigation outlet after June 21, 1990 Manjil earthquake**



**Sefid Rud buttress dam with powerhouse**



**Upstream view of dam**

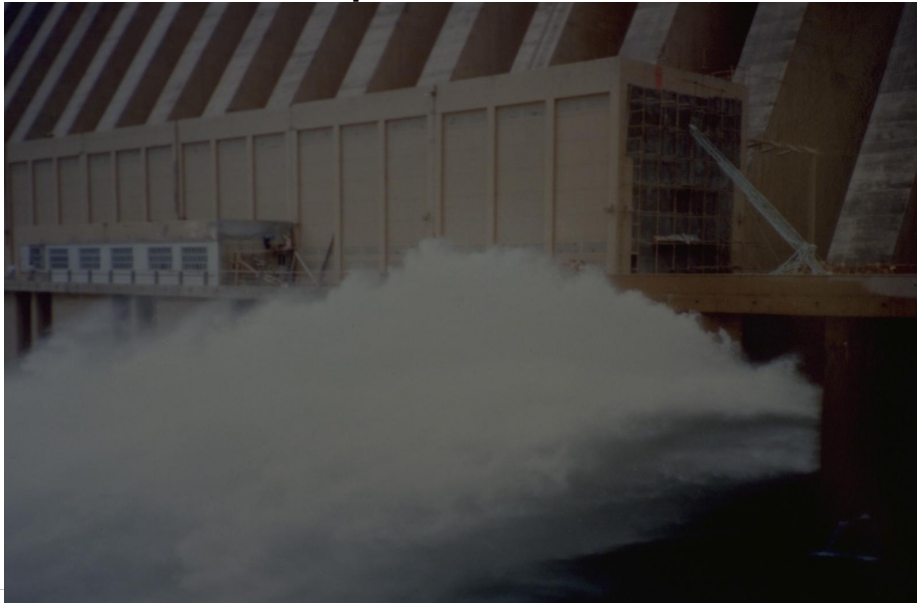


**Dam, powerhouse, irrigation outlet and intermediate level spillway (left bank)**



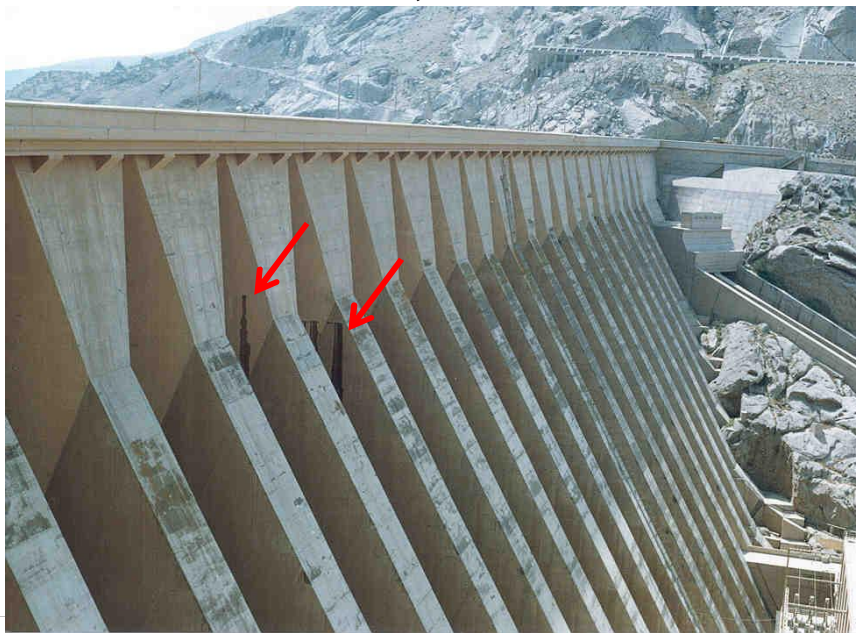


**Open irrigation outlet after earthquake and powerhouse**



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**Sefid Rud buttress dam; horizontal cracks and leakage**

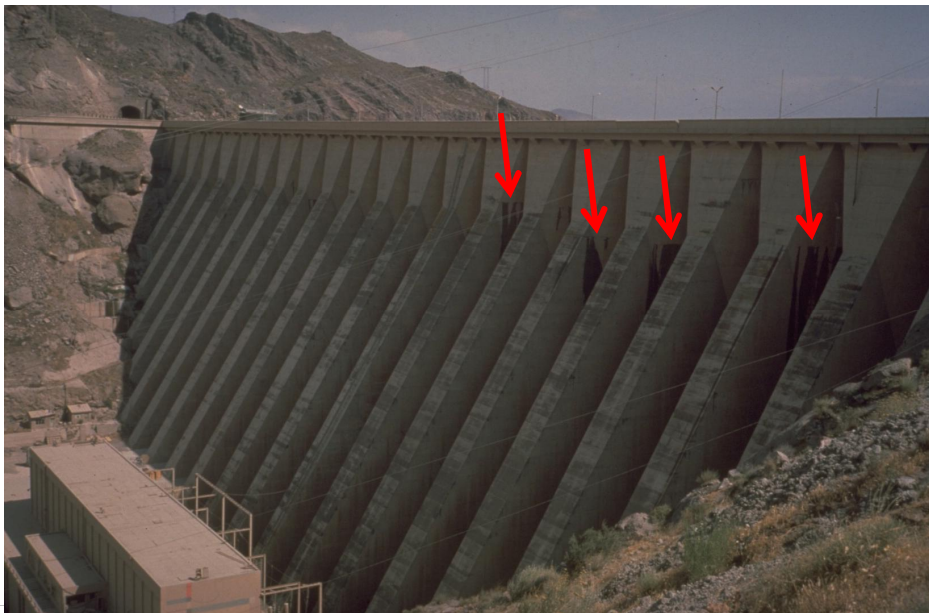


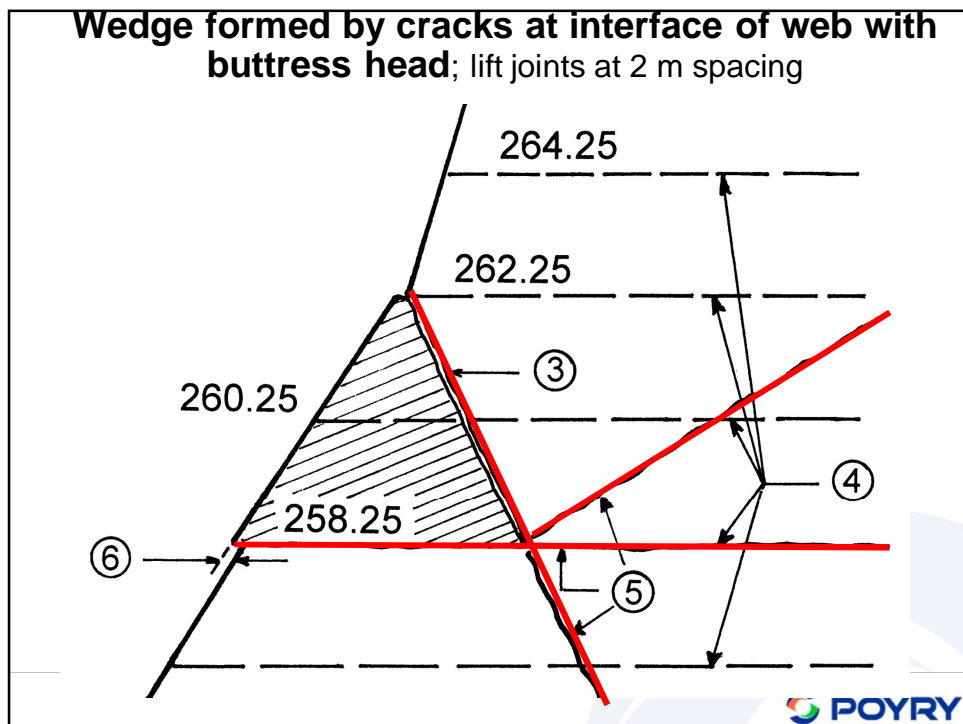
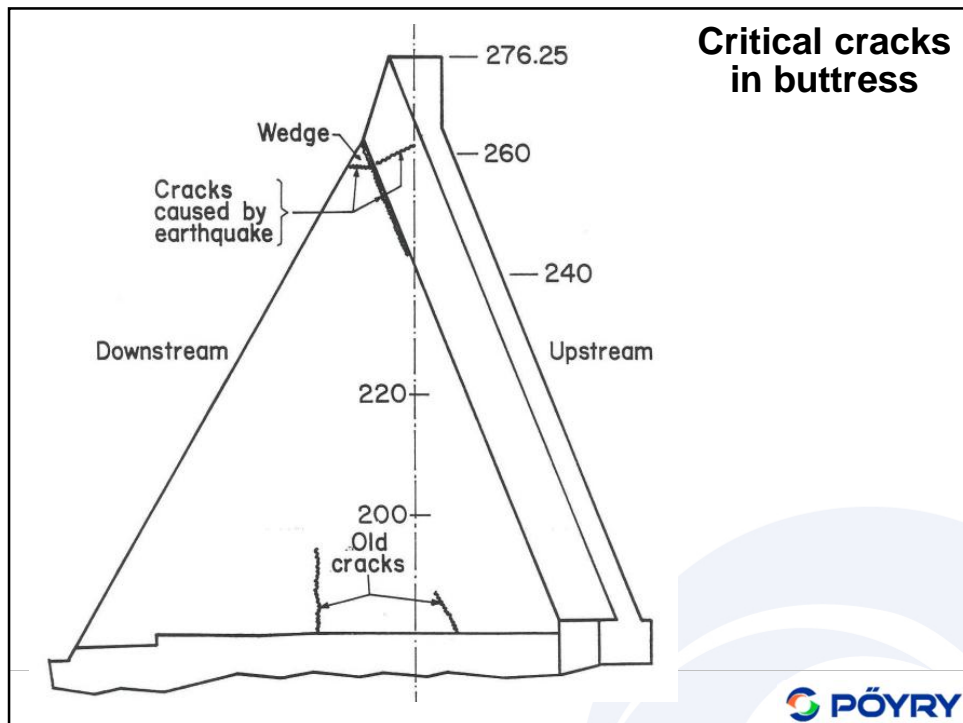
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**Leakage along  
horizontal crack in  
buttress**

**Downstream face of dam with leakage spots**







**Critical crack in buttress of Sefid Rud dam**

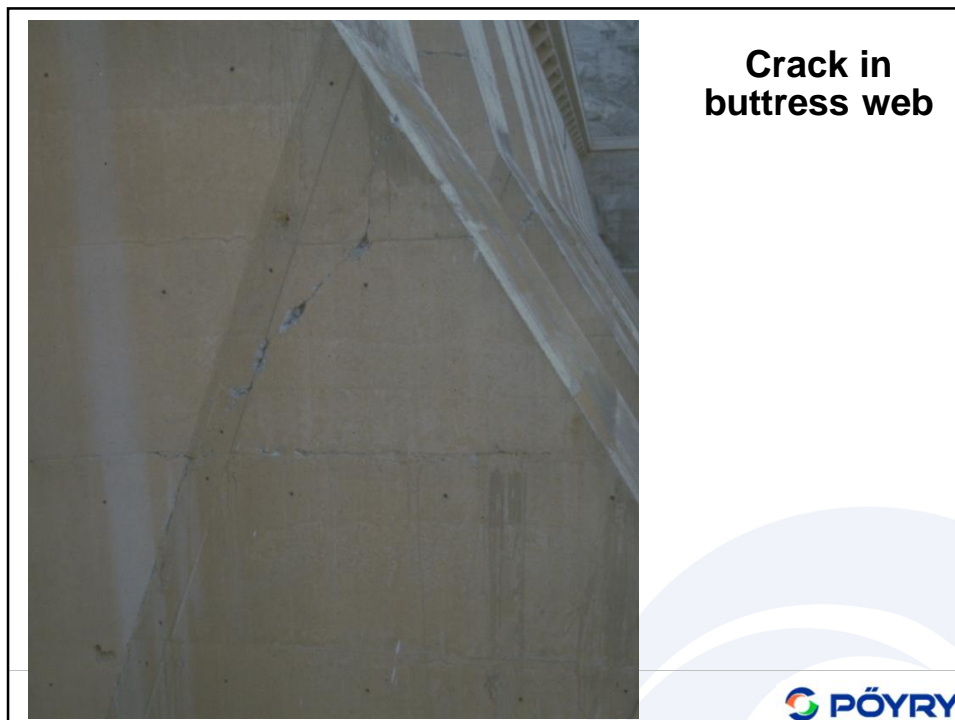


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**Sliding offset of buttress (ca. 3 cm)**



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**Crack along lift joint at upstream face with gate rails**





**Longitudinal cracks on crest and shear cracks  
at buttress joints**



**Joint damage at dam crest**



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**Joint damage in crest gallery (13/14 and 15/16)**



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**Crest deformations at left abutment**



**Damaged downstream parapet wall at dam crest**



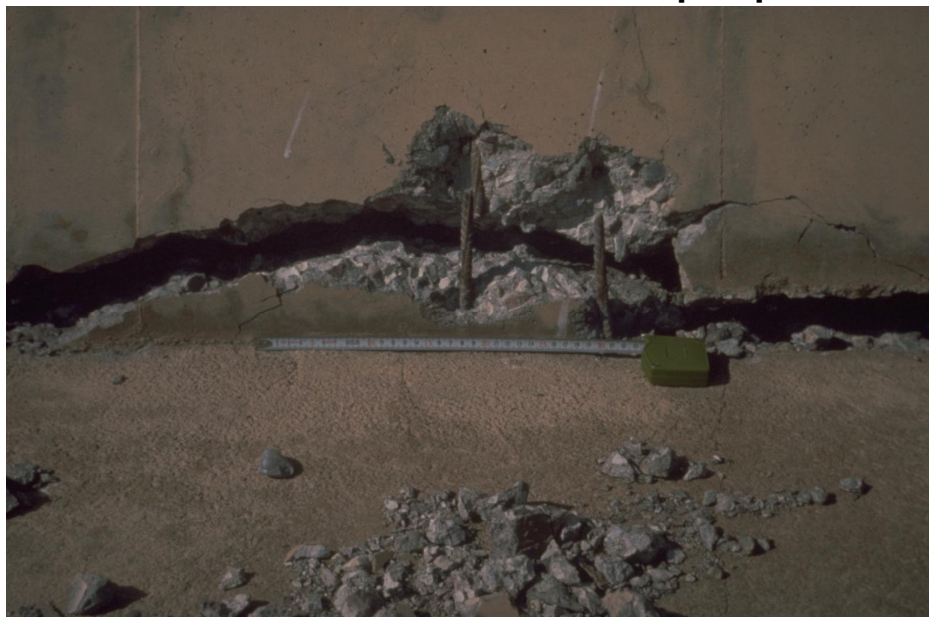


**Secured damaged downstream parapet wall at dam crest to protect powerhouse below**



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**Detail of fractured reinforcement of parapet wall**



 **PÖYRY**

**Damaged upstream parapet wall at gate platform**



 **PÖYRY**

**Damaged upstream parapet wall at gate platform**



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**Sefid Rud dam, reactivated crack in bottom gallery**



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**Morning glory spillway with debris from rockfall**



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**Platform above morning glory spillway with debris**



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**Downstream view of dam with intermediate level spillway**



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**Chute of intermediate level spillway (gate leakage)**



**Buckled arm of radial gate  
of intermediate level  
spillway**





**Leakage of radial gate of intermediate level spillway**



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**Gate leakage; seal damage in corner**



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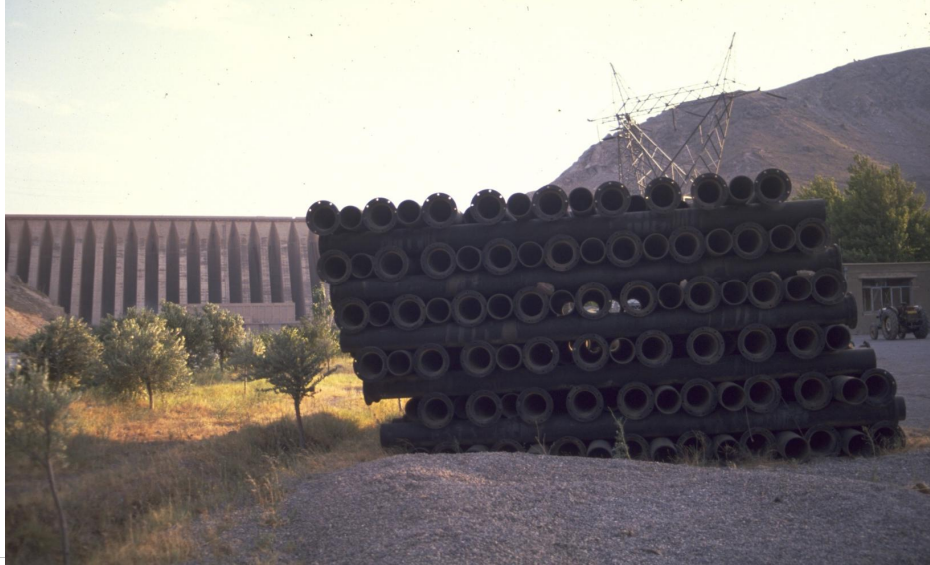
**Damaged concrete lining of irrigation canal**



**Weir of irrigation system with many counterweights for gate lifting fallen down**

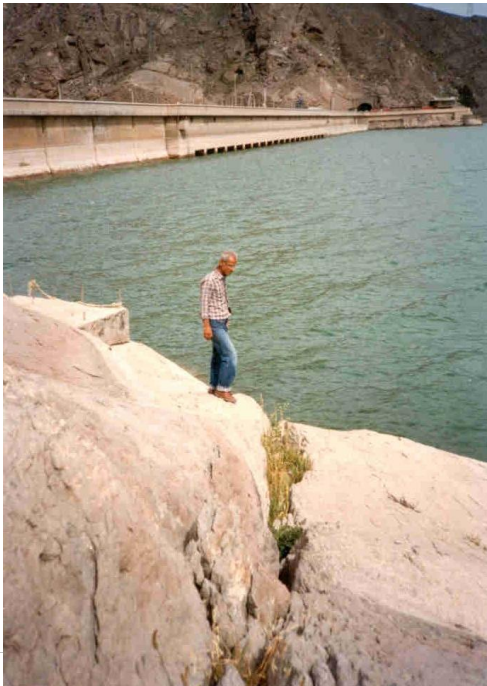


**Stockpile of pipes moving in two horizontal directions**



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**Assumed fault close to dam site**

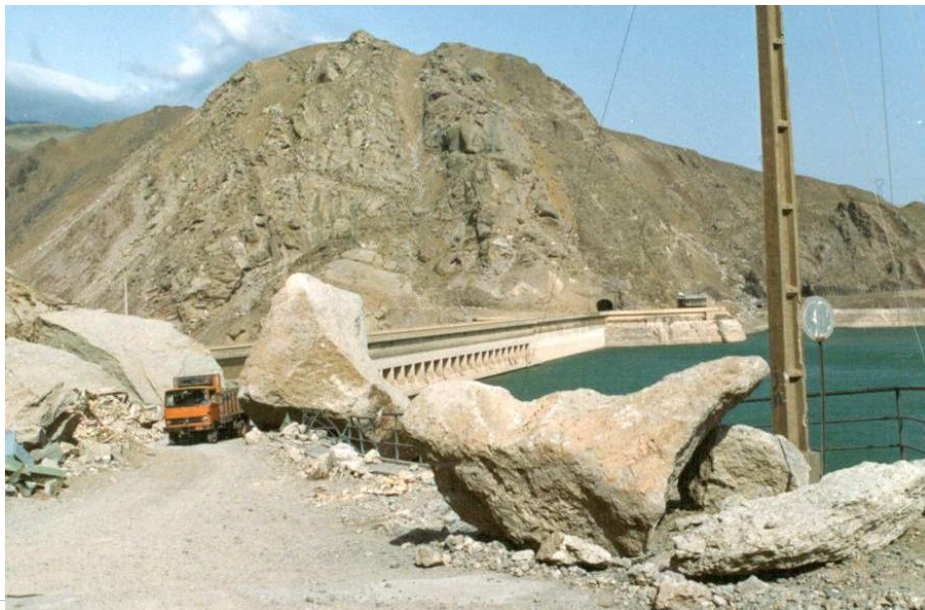


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**Crack in road pavement due to faulting**



**Rockfalls, Sefid Rud dam**





**Rockfall above morning glory spillway**



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**Rockfall near dam crest at right abutment**



 **PÖYRY**

**Rockfall near dam crest**



 **PÖYRY**

**Rockfall near dam crest**



 **PÖYRY**



### Transmission tower failure due to rockfall



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### Rockfall along access road downstream of dam



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**Rockfall near dam crest**



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**Damaged portal of  
access tunnel due to  
rockfall**

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### **Punctured oil pipeline in rockfall area along road**



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**Joint damage in  
powerhouse**  
(columns should be  
stronger than  
beams)

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**Control room of power plant**



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**Switchyard on fill (ground movements)**



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**Ground movement at switchyard on fill**



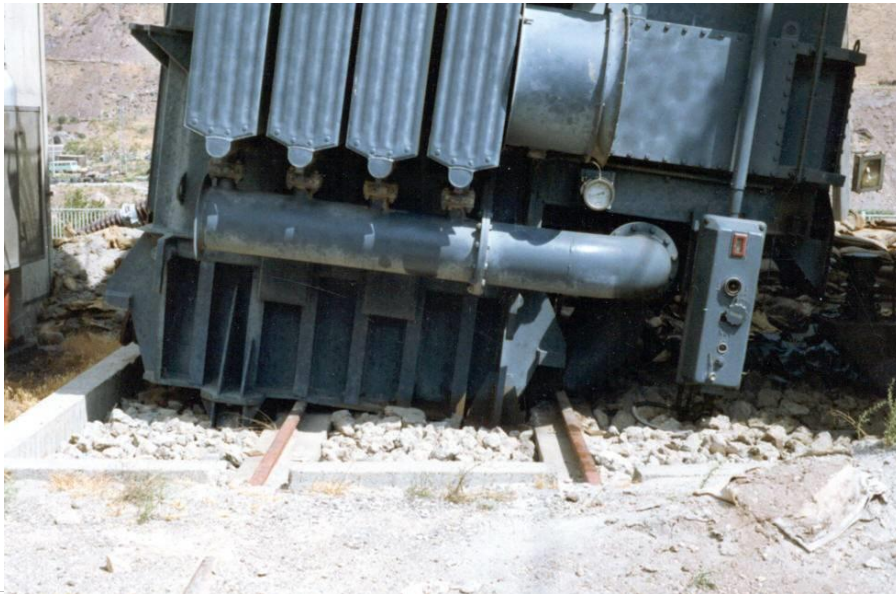
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**Building and switchyard**



 **PÖYRY**

**Derailed transformer**



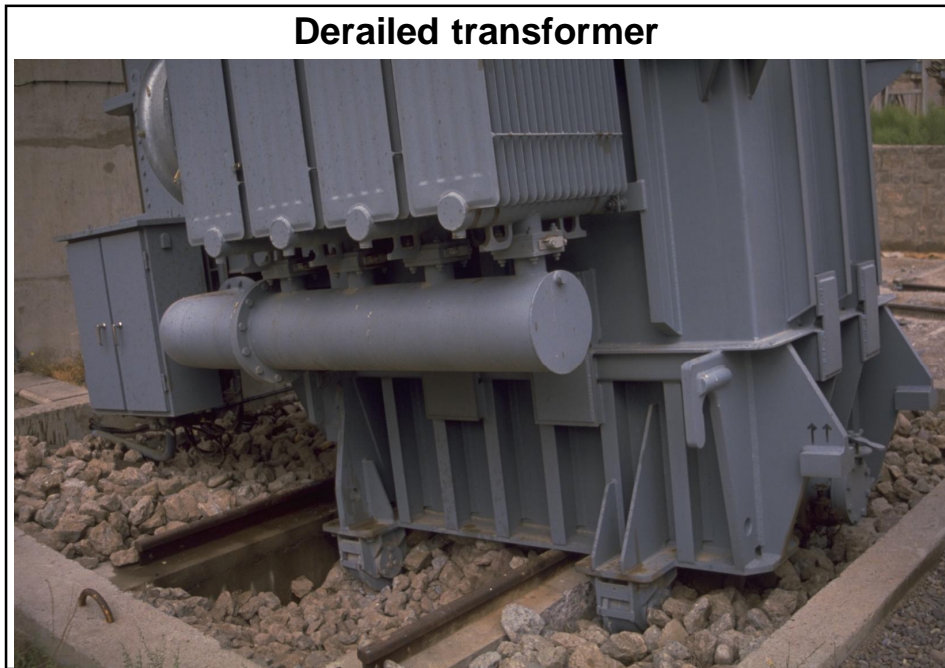
**Damaged transformer**







**Derailed  
transformer**



**Derailed transformer**



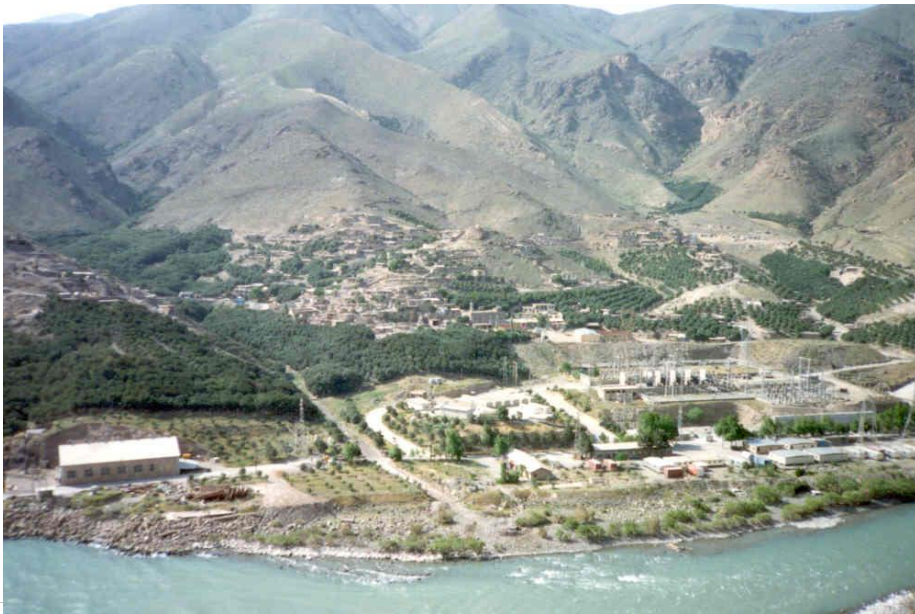


**Building collapse in vicinity of dam**



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**Reconstructed camp and damaged village**



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**Destroyed buildings at Sefid Rud dam site**



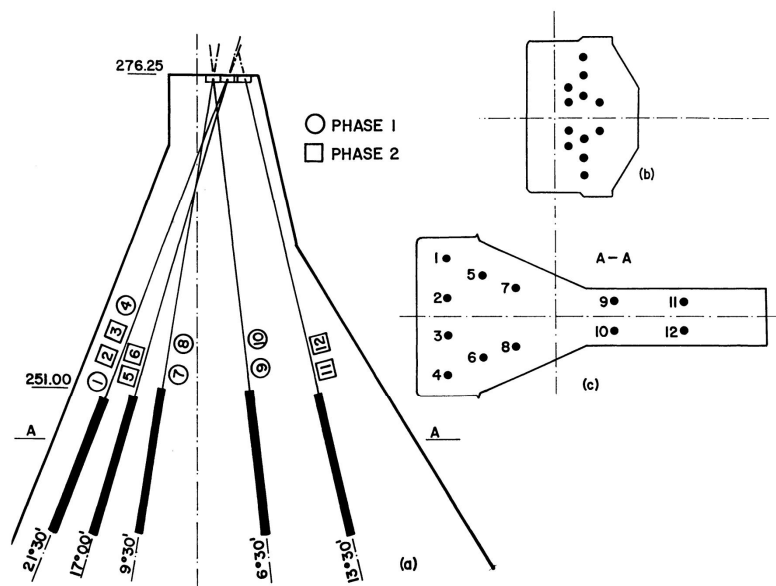
**Damaged buildings at dam site**



## Downstream access bridge



## Dam strengthening by rock anchors (12 anchors with 100 MN/block)







**Drilling of anchor  
holes on dam crest**



### **Rock anchor installation**



**Manjil earthquake 1990, repair works (rock anchors)**



**Crack repair with epoxy grouting (Rodur)**



### Conclusions

- Earthquake hazard is multi-hazard: rockfall hazard has been underestimated in most places. Access to dams is a problem after strong earthquakes, especially in mountainous regions.
- Earthquakes affect all components of storage dams at the same time and all of them must be able to withstand different level of earthquake shaking.
- Cracks in concrete dams are discrete cracks developing along lift and construction joints and at locations with sudden changes in stiffness and/or mass (kinks and corners are locations with stress concentrations)



### Conclusions

- It must be possible to lower the reservoir after a strong earthquake in order to increase the safety of a damaged dam. Furthermore, to control the reservoir level after a strong earthquake, spillways and low level outlets must be operable.
- Hydro-mechanical and electro-mechanical equipment of spillway gates and low level outlets must be capable to withstand the ground motion of the safety evaluation earthquake. Hydrodynamic pressures may damage gates.
- Powerhouse is out of operation after a strong earthquake.

