7. Alkali-Aggregate Reaction Problems

7.1 Initial Findings

During the initial general inspection of the objective bridges, at the time of first visual inspection in Turkey, evidence of extensive cracking was found to substructures of several of the bridges in the Izmir region. The study team, jointly with the engineers from Izmir Division (KGM 2nd Division) and the laboratory people from the KGM Headquarters, the cracks were further inspected and Alkali Aggregate Reaction (AAR) of the concrete was suspected as the primary cause.

The request by KGM to include the investigation of AAR within the scope of the present Study, was accepted by JICA and additional resources were allocated. The Study was expanded to investigate the cause and to promote countermeasures to the cracking in the substructure.

7.2 Sampling and Testing

Sampling and testing to identify the extent of the problem, both in terms of area and time, were conducted in several series since this problem was new to concerned authority in Turkey and not enough information was available at the start.

At the first stage, several samples of concrete cores and material which were believed to be used at the time of construction, were collected and tested both at laboratory in Turkey and Japan. Usual standard of ASTM C289 failed to detect the potential reactivity of material but improved version of Canadian Standard CSA A23.2 - 25A revealed that hill sand collected from the Gediz and Nif river systems, but no other material, was prime suspect of alkali silica reaction. Concrete cores tested in Japan also revealed that some grain of sand contained rhyolite and other related material which were highly reactive.

At the second stage, the site investigation was expanded to cover more bridges and viaducts which were out of initial scope, to determine the extent of the problem. Generally the structures constructed within the last 12 years were showing cracking problems. Among many damaged ones several were selected to have them put in an order of ages of structures, ie. 1, 3, 5, 7-8 and more than 10 years. More sand samples were collected from suspect quarry sites and are shows the result of test in Table 7.2.1 and Figure - 7.2.1.

Presently some of testings are still under going, however, the results obtained so far show that all the sand samples show reactive behaviour although the degree of reaction differ by sample to sample, and structures of younger age show faster reaction than older ones. Figure - 7.2.2 shows the ample photograph of AAR.

7.3 Conclusion and Recommendation for AAR

The result to date indicate that the majority of the natural sand around the Izmir area is potentially reactive. Presently the tests described here as well as further tests by KGM Ankara for additionally collected samples are still under going. There is enough evidence already to conclude that the hill sand in Izmir area is highly reactive to alkali contents of cement and all or some of the recommendation shall be implemented. The measures relate to existing and proposed bridges in the Izmir region.

1) Material Usage
   Hill sand from Izmir region, particularly from Gedis and Nif river systems shall be prohibited for use until definite testing procedure is established.

Until then the crushed rock sand shall be used to substitute the natural sand.

Discussions are held with local cement suppliers to reduce the alkali contents of cement and in future to supply low alkali cement.

Table - 7.2.1 Results of Accelerated Mortar Bar Test Carried Out in Tokyo, Japan.
Results of The Accelerated Mortar Bar Test (CSA A23.2-25A)

Sand Sample	No.	Expansion(%)		
		3Days	7Days	14Days
Sample 1	1	0.029	0.143	0.263
	2	0.028	0.152	0.274
Nif River	3	0.033	0.157	0.285
	AV.	0.030	0.150	0.274
Sample 2	1	0.020	0.133	0.237
	2	0.024	0.125	0.267
Nif Terrace 1	3	0.024	0.121	0.259
	AV.	0.022	0.119	0.254
Sample 3	1	0.024	0.118	0.244
	2	0.026	0.124	0.241
Nif Terrace 2	3	0.024	0.117	0.227
	AV.	0.025	0.120	0.237
Sample 4	1	0.239	0.415	0.502
	2	0.241	0.409	0.498
Ahmetli Gediz	3	0.247	0.425	0.525
	AV.	0.242	0.416	0.508
Sample 5	1	0.032	0.098	0.177
	2	0.032	0.117	0.191
Gölmarmara	3	0.029	0.092	0.170
	AV.	0.031	0.102	0.180
Sample 6	1	0.087	0.156	0.237
	2	0.092	0.159	0.235
Surhanli	3	0.099	0.180	0.258
	AV.	0.093	0.165	0.244

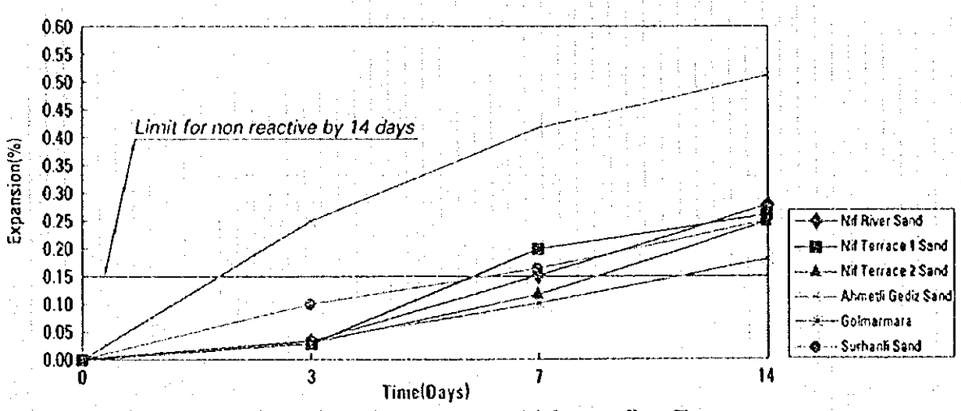
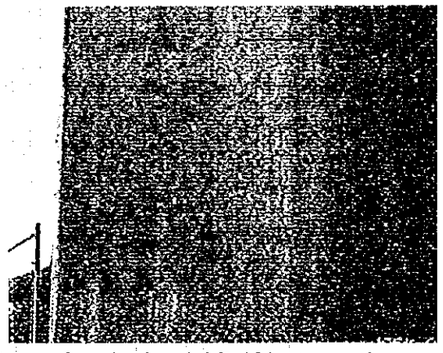
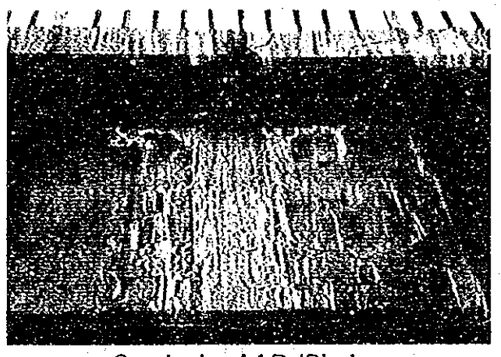


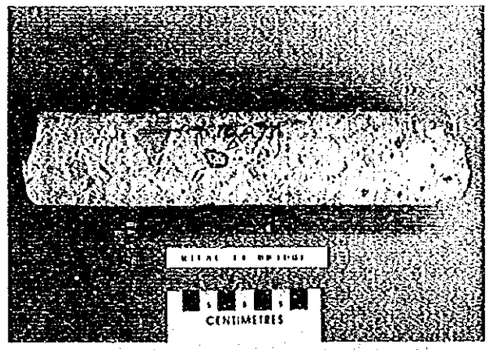
Figure - 7.2.1 Results of Accelerated Mortar Bar Test (CSA A23.2-25A) Testing Carried Out in Tokyo, Japan



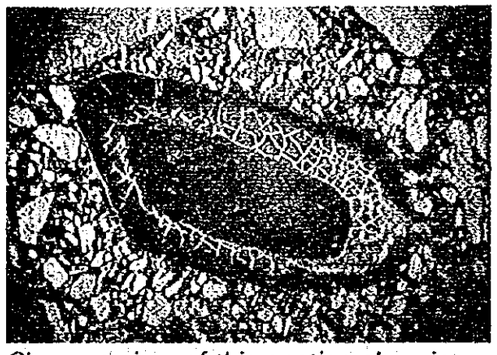
Cracks by AAR (Abutment)



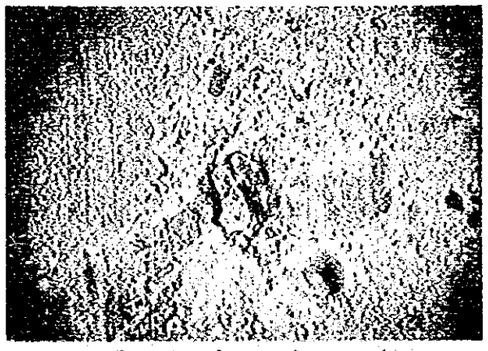
Cracks by AAR (Pier)



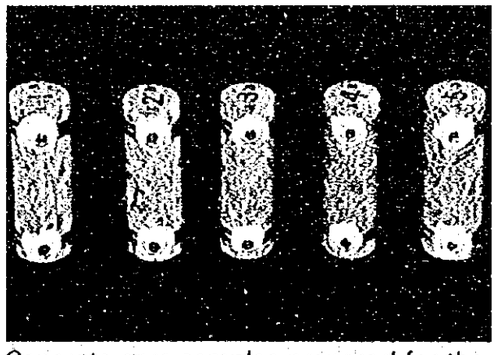
Concrete core sample contains a reacted gravel x 0.4



Close-up view of thin section showing minute cracks in the reaction rim x 6



Pop-out formation on the reacted rhyolite particle x 9



Concrete core samples prepared for the accelerated expansion test

Figure - 7.2.2 AAR Photograph

2) Protective Measures
Structure with smaller than 0.2mm cracks shall be covered with an elastic crack bridging paint to further prevent water vapour penetrating into the structure.

Ones with larger than 0.2mm cracks to seal them with either polyurethane or epoxy based resin by crack injection method.

Where concrete surface spalled, urgent repair is needed to reduce further deterioration of structure.

3) Future Design Mix
Future design mix record should include the source of all aggregate and tested for susceptibility to AAR.

Adequate AAR specification clauses to be included in all future contracts containing structures.

4) Monitoring

Monitoring of the structures is essential in confirming whether the reaction has stopped or not.

8. Conclusions and Recommendation of the MARHB Study

Conclusions from the MARHB Study are as follows:

a. Damage and wear and tear were found in at least a quarter of the inspected bridges and; these bridge need repair works. Some of them are so distressed that they would have to be closed to traffic, if they were in Japan.

b. Many of those defects were caused by poor workmanship and lack of proper supervision during initial construction. Those defects would normally be repaired immediately before the hand over. Some change in attitude of people concerned will be needed.

c. There was evidence of traffic accidents in which over-height vehicles had collided with girders. Special care shall be taken during all the stages of designing, construction, and maintenance to secure enough head room for girders.

d. Excessive excavation of aggregates from rivers is causing foundations and piles to be exposed dangerously. This is a man-made problem and can be easily solved in most situations by regulating those operations.

e. Defects caused by salt were detected on structures along the Black Sea coast. Special care shall be taken during design and construction.

f. Evidence of Alkali Aggregate Reaction was detected and experiments were conducted to prove the existence of the problem in and around the Izmir area. The problem has existed for more than ten years. The administration had failed to detect this and needs to address its approach to maintenance inspection and appraisal.

g. Most of defects are manageable except for a few cases where replacement is needed.

h. Economic evaluation proved that bridge maintenance contributes greatly to the development of a national economy.

i. Environmental study proved that the maintenance works cause a very small, if any impact on the environment. However each case shall be investigated as it proceeds.

j. There are several seriously damaged bridges which require immediate action.

The following recommendations can be derived from the conclusions;

1. Bridge maintenance is an indispensable part of the economic development of Turkey. Hence the operation should be expanded to cover the whole nation as soon as possible.

2. Sensible budget allocation to enable this operation is urgently needed.

3. Several of the bridges which were inspected this time, were found to be in a very dangerous state and require immediate repair.

4. There is a possibility that similarly dangerous bridges may exist on the other routes and urgent inspection work is strongly recommended.

5. Improvement in construction workmanship and supervision are needed.

6. Some measures to secure head room and to regulate over-height vehicles are needed.

7. Strict measures are needed to regulate excessive excavation of aggregate from river beds.

8. There are some areas which require special attention on aggregates selection and salt problems.

9. Concluding Remarks

The JICA Study Team would like to convey their sincere appreciation to all KGM counterparts for their generous hospitality and cooperation during their stay in Turkey, without which this Study would not have been as successful. In particular, the Team would like to thank Mr.Dincer Yigit, Director General of Highways, and many staff of KGM who showed great interest in our work, attended meetings and contributed with valuable opinions to assist in the smooth progress of the Study. KGM counterparts are extremely cooperative and have a very good understanding of the Study, by working together at all stages of the Study, and were vital elements for the successful completion of the Study.

On the Japanese side, invaluable support and encouragement from the Japanese Embassy, JICA Turkish Office and JICA Experts (seconded to KGM) have provided great assistance in the timely progress of the Study.

The JICA Study Team sincerely hopes that the results of the Study will be utilised for the further operation of bridge maintenance and that the responsible organization will be able to receive enough budget and staff to meet this end.

JICA