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Durability Assessment of the Mortars of Ganga Canal System

Evaluation de la durabilité des mortiers du Canal du Ganges

Bestimmung der Dauerhaftigkeit der Mörtel im Ganges-Kanalsystem

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SUMMARY

Investigations on the durability assessment of lime based mortars and plasters of bridges and related structures of the Ganga Canal system after a span of about 150 years show that the mortars possess good compressive strength. Since there is no evidence of the presence of calcium hydroxide, indications are that the mortars are heavily carbonated and almost all of the calcium hydroxide has been converted into the strength giving mineral 'Calcite'. The studies thus reveal that the examined mortars are in a sound state.

RÉSUMÉ

Des études pour l'évaluation de la durabilité des mortiers et plâtres des ponts et des structures annexes du Canal du Ganges, qui a plus de cent cinquante ans, ont été réalisées. Elles montrent que les mortiers présentent une bonne résistance à la compression. Comme il n'y a pas d'évidente présence d'hydroxide de calcium, cela indique que les mortiers sont très fortement carbonatés et que presque tout l'hydroxide de calcium a été converti par compression en un minéral calcite. Les études révèlent ainsi que les mortiers du Canal du Ganges qui ont été examinés, sont en bon état.

ZUSAMMENFASSUNG

Die Studien dienten der Zustandsbeurteilung der bei Brücken und angrenzenden Bauwerken im Ganges-Kanalsystem vor rund 150 Jahren verwendeten Kalkmörtel und Verputz und zeigen, dass der Mörtel eine gute Druckfestigkeit aufweist. Nachdem keine Hinweise auf das Vorhandensein von Kalziumhydroxid hindeuten, kann abgeleitet werden, dass der Mörtel stark karbonisiert ist und das Kalziumhydroxid praktisch vollständig in Calzit umgewandelt wurde. Die Studien belegen also den guten Zustand der im Ganges-Kanalsystem untersuchten Mörtel.

1. INTRODUCTION

In a structure, the selection of building materials is made to ensure its future performance i.e. durability. Durability is usually considered as a property of resistance to a slow rate of detriortion to environmental factors. A more durable structure lasts for a longer period. Selection of any building material for use under any given situation is made with the knowledge of the performance of the material under the required circumstances. Several sophisticated and accelerated methods are available now a days for assessing the durability of a material. But in olden days, the long term performance of a material was the only synonym considered for assessing its durability. Thus, on the basis of the materials evaluation, much could be known about the performance and durability of a structure.

Lime has been used as a material of construction since the dawn of civilization. In india definite evidences of its use have been available in the remains of the Indus valley civilization at Harappa, Lothal, Mohanjodaro and other places as far back as at least 5000 years ago. Lime mortar [1] was used in the construction of pyramids of Egypt. Greeks used mortars based on lime to cover the walls made up of unburnt bricks. Romans perfected the use of lime mortar by adding pozzolanic material. Beside historic buildings and monuments [2] various hydraulic structures, such as dams, canals embankments etc. have also been made in lime mortars and concrete.

However, use of lime has its own merits in construction. Lime provides better workability, greater water tightness, high plasticity, better volume stability, autogenous healing capacity, high water retention value, good adhesion and is itself a durable material.

2. GANGA CANAL

Ganga canal [3] is one of the oldest water carrying system in India, streching over 563 km and carrying 6750 cusec of water, was constructed during 1839-1858 A.D. is a unique example of ninteenth century achievements. In all the works of canal, lime and "surkhi" (Burnt clay pozzolana) as a binder was used in mortars and plasters. Lime was obtained through calcination of highly calcareous lime stones from the quarries of Dehradun (Northern India) or collected from the basins of the rivers in the area, it generally is fat. Downstream, however, limestones characterized by the presence of earthy materials were used. Enhancement in hydraulic property of fat lime was achieved by the incorporation of "surkhi" obtained by grinding overburnt bricks to a fine powder. The mortar was further fortified by the addition of traditional materials like jute fibre, ground lentils, geleteneous wild fruits or jaggery. All the constituents were thoroughly wet ground together to a fine paste before use.

The composition [4] of the mortars used under various situations are given in Table 1.

3. COLLECTION OF SAMPLES

A number of lime mortar samples for examination were collected from different situations. First set of samples were collected

TABLE - 1

MORTARS AND PLASTERS USED IN GANGA CANAL SYSTEM

SITUATION	COMPOSITION		
	LIME	SURKHI	SAND
Inlet and dam rivers	1S	2	-
Arches of the bridges	1R	1	1
Bridges (Class I)*	1R	1	-
Bridges (Class II)*	1K + 0.05 S	1	-
Bridges (Class III & IV)*	2K	1	-
Inspection House	1R	1	-
Chokies	1R	1	-
Finishing works	7S	1	-

S - Stone lime; K - Kankar lime; R - River lime

*Classification of bridges are based on the span and breadth.

from Dhanauri bridge which is a class I bridge and is situated at 23 kilometer downstream from the origin of the canal at Hardwar at a very stratigiic situation, where Rutmov river level crosses the Ganga canal.

Second set of mortar samples were collected from the inspection house at Pathri, which is situated 11 kilometer downwards Hardwar. This is also very interesting situation, as the canal has to cross the voluminous monsoon river Pathri, which is flowing at a higher level. The canal, therefore, has to pass under the river.

Several chokies (security posts) were constructed along the length of the canal. Third set of mortar samples were collected from these chokies.

In all the cases, while collecting the samples, effort was made to take out the entire mortar. Attempts were also made to collect the samples from the situations as distant from each other as was possible under the circumstances, so that the statistical variations could be accommodated.

4. EVALUATION OF MORTAR SAMPLES

The samples collected from different situations of the Ganga Canal system were evaluated for various properties i.e. compressive strength, free lime content and pH values. For chemical characterisation the samples were subjected to thermal and X-ray diffraction analyses.

4.1 Compressive strength

The strength under compression is the primary function of any structure and therefore, is the most important property of the materials. In addition, the compressive strength is also a good index of many other engineering properties

Lime based mortars gain strength predominantly by carbonation process [5] by the absorption of atmospheric carbon dioxide (to convert lime into calcium carbonate) which continues over a considerable period of time. Further development of strength can take place by the reaction between lime and the oxides of silicon and aluminium added in the form of "Surkhi" [6] to generate calcium silicates and aluminates.

For measurment of compresive strength, cubes were cut from the lime mortar samples. These were of 40 mm of size. Some of them were some what smaller. Six cubes were tested on a compression testing machine of two tonne capacity. The average compressive strength values of the tests are reported in Table-2.

TABLE - 2

COMPRESSIVE STRENGTH OF MORTAR CUBES

SITUATION	Average Density (Kg/m^3)	Average Compressive Strength (MPa)
Dhanauri bridge	1520	5.76
Inspection House	1850	8.60
Choki (security post)	1715	5.24

4.2 Free lime content

The strength of lime based mortars mainly depend on the amount of lime present. Therefore, the estimation of the amount of lime present in the set mortar samples become important. Amount of lime present in free or uncombined state was determined by the modified Frankie method [7]. Approximately 1 g of the dried sample was taken in an Erlenmayer flask together with 10 ml of acetoacetic ester and 60 ml of isobutyl alcohol. The mixture was refluxed over a water bath for 2 hr. After cooling, the contents were filtered under vacuum and the residue washed with isobutyl alcohol was titrated against a standard perchloric acid solution using thymol blue as indicator. The results of three typical samples are given in Table - 3.

4.3 pH Value

The presence of free lime content in the mortar samples were further confirmed by the pH determinations. The pH values of the aquous extracts were determined with the help of a Phillips precision pH meter model PR 9405 M. Twentyfive grammes of powdered sample was taken and mechanically shaken for two hours with 100 ml double distilled water and allowed to stand for 22 hrs. These were then filtered and pH values determined. The results of three typical samples are given in Table 3.

TABLE - 3

FREE LIME AND "pH" VALUES OF MORTAR SAMPLES

SAMPLE	FREE LIME (%)	pH VALUE
M-1	0.09	8.0
M-2	0.11	7.4
M-3	0.12	7.6

4.4 Thermal Analysis

For further information, the mortar samples were subjected to thermogravimetry (Fig.1), differential thermogravimetry (Fig.2) and differential thermal analysis (Fig.3) with the help of Simultaneous Thermal Analyser, model STA-1500 with Trace-II system (PL Thermal Sciences Limited, U.K.). The rate of heating were maintained at 10°C per minute and the temperatures were measured with a plati- num-platinum - rhodium thermocouple. A sample of alumina was used as a reference material.

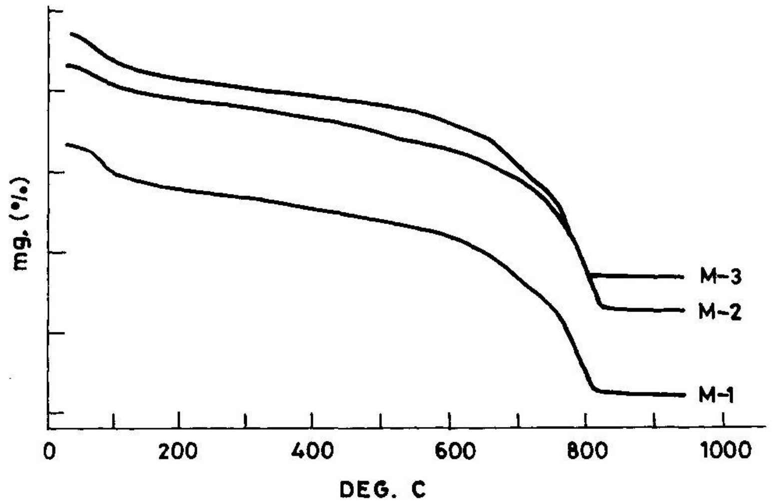

FIG. 1. THERMOGRAVIMETRY CURVES.

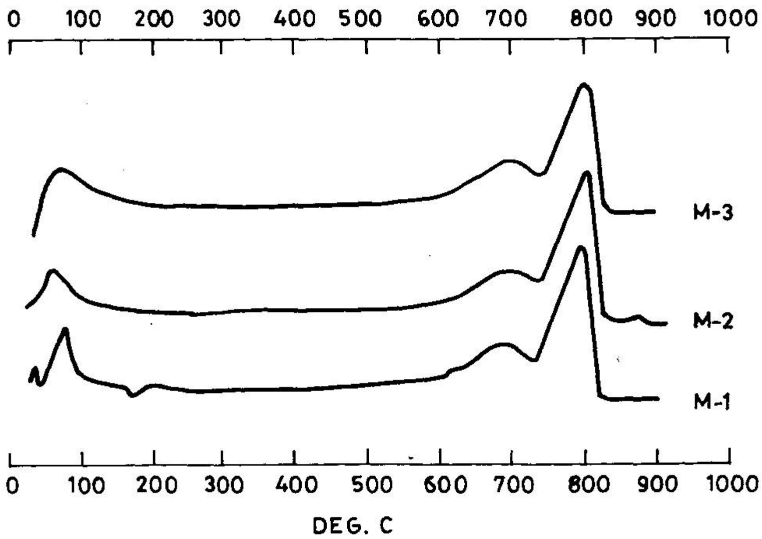

FIG. 2. DERIVATIVE THERMOGRAVIMETRIC CURVES.

The most significant observations are the strong endothermal effects between 734°C and 832°C, due to the presence of calcium carbonate decomposition and are supported by DTG curves. These changes can be assigned to the presence of the mineral calcite [8,9]. Broad endothermal effets in DTA curves between 660°C to 760°C and suspported by corresponding weight loss in DTG curves, appear to be due to the presence of amorphous or poorly crystalline calcium carbonate [10]. A weak but sharp endotherm around 575°C (not shown by DTG) is due to the transformation of mineral quartz. The exothermic effect in DTA at 174°C (only in sample M-1) is also accompanied by a loss in

DTG curve, can be due to the presence of cellulosic material; which, as evinced due to the incorporation of some local material [4] during the preparation of the mortars.

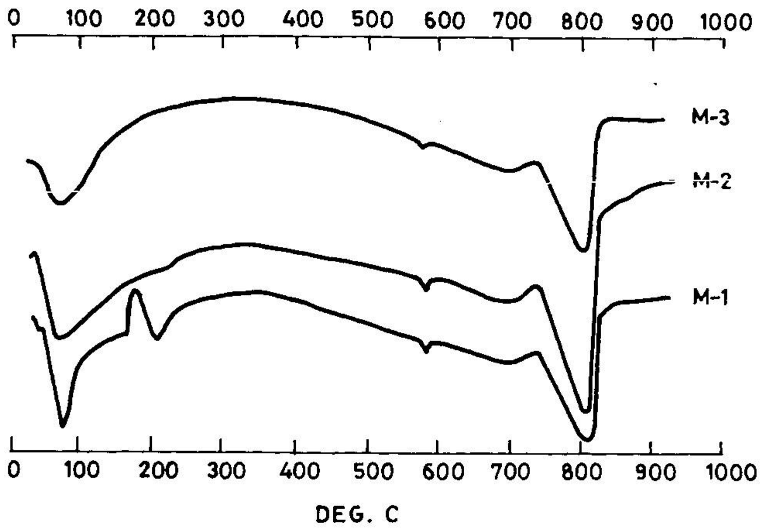

FIG. 3. DIFFERENTIAL THERMAL ANALYSIS CURVES

4.5 X-ray diffraction

The X-ray diffraction (XRD) patterns (Fig. 4) were also obtained by means of Phillips X-ray diffractometer, Model PW 1760, using Ni filtered CuKα radiations. The powder specimens were placed in a recess in a plastic plate, compacted under just sufficient pressure to cause cohesion without the use of a binder. The results obtained were compared with standard data from ASTM powder diffraction file.

The X-ray diffraction patterns obtained in all the three mortar samples strongly support the presence of minerals calite, quartz and magnesite [11].

5. CONCLUSION

The results indicate the presence of very little amount of calcium hydroxide, which was confirmed by the "free lime" and pH determinations. From thermal and X-ray diffraction experiments the most prominent observation is the presence of calcium carbonate, which indicate that the calcium hydroxide added to the mortars has been converted almost completely into strength giving mineral calcite. This is also evident from the fairly good amount of compressive strength values of the mortars.

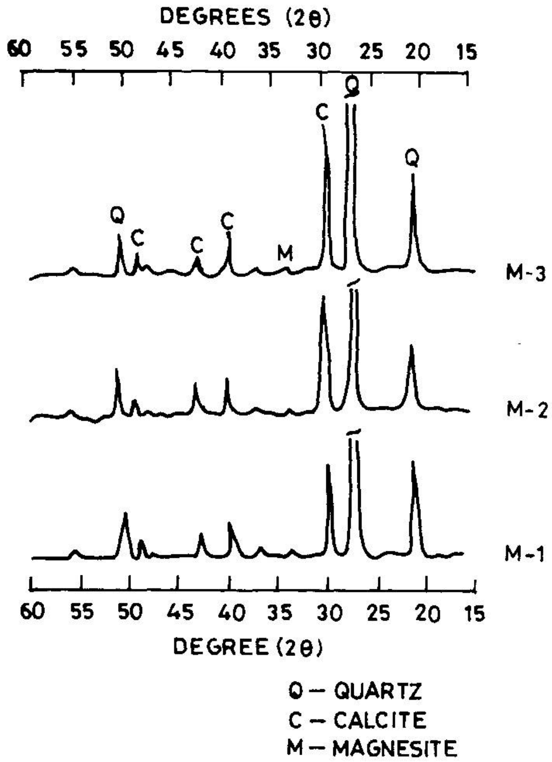

FIG.4. X-RAY DIFFRACTION (XRD)

The presence of poorly crystalline or amorphous calcium carbonate is also envisaged due to the process of dissolution of CO_2 through water into lime and "Surkhi" paste and this process continues over a long period through capillaries even after the paste has set. The hydraulic products of lime and silica and/or lime and alumina reactions may not have been formed or if had formed, might have also undergone carbonation.

The observations, therefore, reveal that the mortars, of Ganga canal system possess good compressive strength even after a long period of about 150 years. These structures, therefore, are in sound state and likely to remain serviceable for many more years.

6. ACKNOWLEDGEMENT

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