ENGINEERING NEWS

Vol. XXV SEPTEMBER, 1980

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(14)

A QUARTERLY JOURNAL OF
PAKISTAN ENGINEERING CONGRESS

IQBAL AHMAD BEG

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It is indeed with a heavy heart that we take up our pen today to record the obituary of such a dear and learned colleague as Iqbal Ahmad Beg, Member Punjab Engineering Congress Council who left us on 16.6.1980, after a short illness. Born in 1931 at Panipat, after going through the basic education in his home town he migrated to Pakistan, joined Government College, Lahore and graduated in Engineering from the Punjab College of Engineering and Technology Lahore in 1952. He completed his post Graduate studies in Advance Sanitary Engineering from Bhabaura Institute of Technology Tokyo, Japan. He also graduated in law from Law College Lahore in 1972. He had a varied experience in various posts of responsibility in the Provincial as well as Federal Government.

He was known for his zeal and energy and was an active member of Pakistan Engineering Congress, Institute of Engineers (Pakistan) and the Pakistan Society of Public Health Engineers and quite a few other Institutions. He had endeared himself to all not only by his hard work, Zeal and Professional ability but also by his ready wit and sense of humour with which he enlivened the proceedings wherever he was present. He has departed from us at the early age of 50 years leaving behind a widow, one son and a daughter and counless admirers & friends ever to mourn his loss. We express our heartfelt sympathies to the bereaved family.

TWENTY FIFTH YEAR OF PUBLICATION

ENGINEERING NEWS

Quarterly Journal of the Pakistan Engineering Congress

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Publication for Members only.

BIO-DATA OF MR.ASHFAQ HASAN, PRESIDENT OF PAKISTAN ENGINEERING CONGRESS

Mr. Ashfaq Hasan was elected as new President of Pakistan Engineering Congress in the A.G.M. held in September'78. He was born in Multan on 25th April, 1924 and obtained his B.Sc. Engg. degree in Civil Engineering from erstwhile Punjab College of Engineering & Technology, Lahore in 1945 in I Division. Soon after graduation, he was selected by the Punjab Government of undivided India for Postgraduate Studies under Post War Reconstruction Scheme launched by the then Government of India.

He proceeded to U.K. in January 1946 but joined the City & Guilds College (a component of the Imperial College London) in October 1946 to pursue Postgraduate Studies from the beginning of the Academic Session. He worked with a renowned firm of Consulting Engineers (B.R.C. Engineering Co. Ltd.) to obtain practical design experience in their Design Office at Stafford during period April 1946 to September 1946. He obtained Diploma of Imperial College (DIC) London in Concrete Technology for Design of Reinforced Concrete Jetty in the first year. In the 2nd year he conducted a study on theory and design of Flat plate structures (now popularly known as Folded plate structures) and was awarded a degree of M.Sc. Engg. of the London University.

He returned to Pakistan in February 1949 and joined the B&R Branch of PWD in June 1949 as an Assistant Engineer. He was promoted to the rank of Executive Engineer in June 1953 and then as Superintending Engineer w.e.f. December 1959. He was promoted as Deputy Chief Engineer in November 1969 but continued to hold the post of Director Building Research Station Lahore in the upgraded capacity. He was selected by Federal Government as Chairman Works & Housing Research Council Pakistan in December 1972 and held this assignment till April 1974. In May 1974, he was posted as Member (Tech) C.D.A. Islamabad which post he held till September 1975. He was appointed Chief Engineer Building Department, Punjab in April 1976 and was then posted as Secretary C&W Government of Punjab w.e.f. 1.7.78. Since December, 1978, Mr. Ashfaq is working as Member (Tech) against a newly created post in the P&D Board Government of Punjab, Lahore

During his 36 years of Engineering experience since graduation, Mr. Ashfaq Hasan spent 4½ years in postgraduate studies and specialized training. Of the balance of about 31 years he spent as long as 10 years in Building Research and established the Lahore BRS in 1961 which organization he headed as Director till 1972. The remaining about 21 years of his career were spent on execution and maintenance of Roads as well as Building projects in the Punjab apart from planning, design & development of works in Head Offices of the Provincial Government.

He was the first Engineer of the Sub-Continent to have been awarded the coveted Nuffield Fellowship by the Nuffield Foundation London in Applied Science in 1963 and spent about 1½ years in England - first at the C&CA Labs and then at BRS London. At the BRS London, he conducted research on analysis of warmth and cold of an individual and wrote a paper which was published by the BRS London as an internal note.

He was invited to act as a Short-term Consultant to the United Nations at ECAFE (now ESCAP) headquarter at Bangkok for writing two U.N. documents for Seminar on Building material Industries. He spent two months on this assignment in 1967 and produced two papers - one on "structural clay products" and the other on "Building Lime". These papers were also presented by him to the Seminar in Bangkok in January 1968.

Mr. Ashfaq Hasan also had the opportunity of travelling to India in 1962 to attend a Symposium on "Common Defects in

Buildings" held in New Delhi. He attended an R.C.D. Course of the Pakistan Administrative Staff College Lahore in 1971 and visited Iran & Turkey as a part of the study course. Besides he attended a meeting of CENTO Working Group in Tehran in 1974 on "Tectonics" as a Pakistani delegate.

He has so far written about 3 dozen Research Papers of which more than half a dozen were published in International Magazines abroad. The most noteworthy publication pertains to study of size of bricks on which two of his Papers were published in England- one by the International Modular Group in its official magazine " The Modular Quarterly" in 1964 and the other by the Institute of Clay Technology in its official organ"Claycraft" in 1966. Mr. Ashfaq Hasan has been advocating adoption of 4" Modular bricks which are more economical than Conventional bricks in almost every respect. These bricks are now being used in some of the buildings in Lahore and his study is at long last being rewarded.

Mr. Ashfaq Hasan has been a keen sportsman throughout his career. He was the Member of London University Badminton Team in his College days and also represented the Imperial College London in Tennis and Squash during 1946-48. He won the Inter-Universities Badminton Championship in U.K. in 1948 and also reached to "Runner up" stage in the Punjab Badminton Championship in 1950.

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LIME SAND MORTARS FOR BUILDINGS

By

Ashfaq Hasan*, M.Sc. Engg. (London),
DIC(London), B.Sc.Engg.(Pb),
FIE (Pak)

INTRODUCTION

Lime mortar has been used successfully in buildings throughout the World for centuries. Amongst the oldest buildings in which lime was used as mortar and plaster, the remains of over 4000 years old buildings of Mohinjodaro in Pakistan furnish a proof of success of lime. In fact lime was the only cementing material known to man upto about middle of nineteenth century after which cement, the wonder material of our times, edged out lime due to its superior engineering and structural qualities. It was soon realized that lime could not do what cement can. Even so, it has not been possible to eliminate lime completely from building activities in the advanced countries where masonry mortars and plasters without additive of lime or plasticizer are not permissible and are unthinkable. Lime is added to cement-sand mortars for a number of distinct advantages given in the paper. In U.S.A. plain cement-sand mortars for plasters and mortars were suspended in about 1919 when an investigation into cracking and leakage of several buildings was reported by Kirkpatrick and Orange due to cement masonry.

A popular misconception, that Hydraulic lime is the only suitable quality of lime for use in mortars, must be dispelled at the outset. In the pre-cement era, Hydraulic lime was the only known cementing material for use under damp conditions otherwise mud mortar was ued in common buildings. But old

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monumental buildings used lime, and most probably high calcium lime (popularly known as fat lime) in its construction. The very fact that lime mortar used to be grinded in olden days and was prepared from putty suggests that hydraulic lime could not have been used as it is not possible to make putty with hydraulic lime. The strength of fat lime mortars is undoubtedly less than that of hydraulic lime mortars in the initial stage but ultimately (over long periods) the former gains strength by carbonation and proves equal to latter.

An attempt has been made in this paper to bring to focus the engineering qualities and technology of making lime mortars. Unfortunately the modern engineering has shifted its educational emphasis to cement and concrete with the result that our fresh men, who are going to be future torch bearers, are unaware of lime as a building material except for white washing. The pity is that most of engineering books coming from advanced countries do not throw enough light on lime and so the teachers tend to skip over this important material. In the advanced countries, major research on lime probably culminated by 1930, after which masonry mortars got standardized and lime became not only a necessary additive to cement mortars but also started being used as lime sand mixes for masonry. In Pakistan, lime should play a more positive and active role in building activity for a number of reasons. Firstly because lime is available in abundance; secondly because it requires much less capital to instal a modern lime plant (including production of dry hydrate) than cement plants; thirdly because lime has superior engineering qualities than cement for mortars and plasters; and fourthly because the lime mortars are cheaper than cement mortars. If we are successful in re-introducing lime in mortars and plasters, it may be possible to even export cement without having to invest on expansion of expensive cement plants.

Lime (or Calcium Oxide as it is chemically known) is manufactured by heating, lime-stone (Calcium-Carbonate) to a temperature between 950^{o}-$1300^{o}C$ to drive out Carbon Di-oxide. What is left is Calcium Oxide in lumps which is soft and hygroscopic; it absorbs moisture and Carbon Dioxide from atmosphere to form Calcium Hydroxide and finally Calcium Carbonate. By adding correct quantity of water to lime, it is transformed into dry powder after evolution of heat. The powder is infact stable Calcium Hydroxide and is known as dry hydrate of lime. If the quantity of water is insufficient, some percentage of lime would remain unslaked but even so, it is not injurious for use in mortars as extra water is always added at building sites while preparing mortars. On the other hand if excessive quantity of water is used, instead of dry powder what one may get is damp powder or lime paste depending upon quantity of water. It is not possible (at least n o t easy) to market wet hydrate of lime directly without going through an expensive process of expelling excess water and grinding lime hydrate. From theoretical point of view, every ton of lime requires 72 gallons of water for complete hydration but since the reaction is violently exothermic, some water is lost in steam which must be added if steam is allowed to escape from a Hydrator. The dry hydrate is manufactured in a lime hydrator and is then air separated into various grades and fineness before being bagged and sealed for various commercial uses.

The hydration plant including lime burning kiln, air separator, grinder and bagging machine is estimated to cost at the most Rs.100 lacs in foreign exchange for an output of about 100 tons per day. The total investment on the plant including installation and buildings may be in the neighbourhood of about Rs.200 lacs. That is to say that cost of installation of lime plant would come to Rs.560 per ton per year as against Rs.1200 to Rs.1500 per ton required for a Cement plant. Since mortar is consumed in volume on all the building sites and since lime is lighter than cement, the weight of lime required to replace a given volume of cement will be much less. In actual fact one ton of cement, measuring 25 cft. in a mortar, is replaced by about 500 kg dry hydrate which means that effective capital cost of lime plant per annual ton will be only about Rs.280 as against Rs.1350 (average) per ton of cement. The huge saving in capital cost by introducing lime burning and hydration plants in place of additional cement plants is well nigh evident and worth exploitation. Evidently, from economic standpoint alone, it is much better to use lime instead of cement on those items of construction where cement can be avoided or saved e.g. base concrete, masonry, plasters and pointing which are presently consuming about 30% of cement in a brick building.

MANUAL HYDRATION

Till such time as mechanical hydrators are available, something ought to be done to produce dry hydrate at site of work. Quick lime broken into small pieces, not more than 2 inch gauge, is spread on cemented floor in a layer of about 6" thickness to which water is added by a rose can, while lime is turned over by showels. The quantity of water to be added is about 4 gallons per 40kg this takes account of about 28% of water likeky to escape as steam. After sprinkling of water and thorough mixing, the mixture is allowed to remain for a day The resulting powder is ready to be used in mortar just like cement. The precautions to be taken are that lime should be protected from atmosphere by covering with bricks after hydration and the hydrate be screened through 25 mesh screen before use.

Another method of slaking is to take a basket full of lump lime and immerse it in a tank of water till no more air bubbles are seen to escape. The basket is then withdrawn and emptied into a drum to allow hydration process to complete for a day. According to American standard, coarse lime having particle size between 90 and 600 microns is permissible in building works and as such manually hydrated lime will generally pass this test.

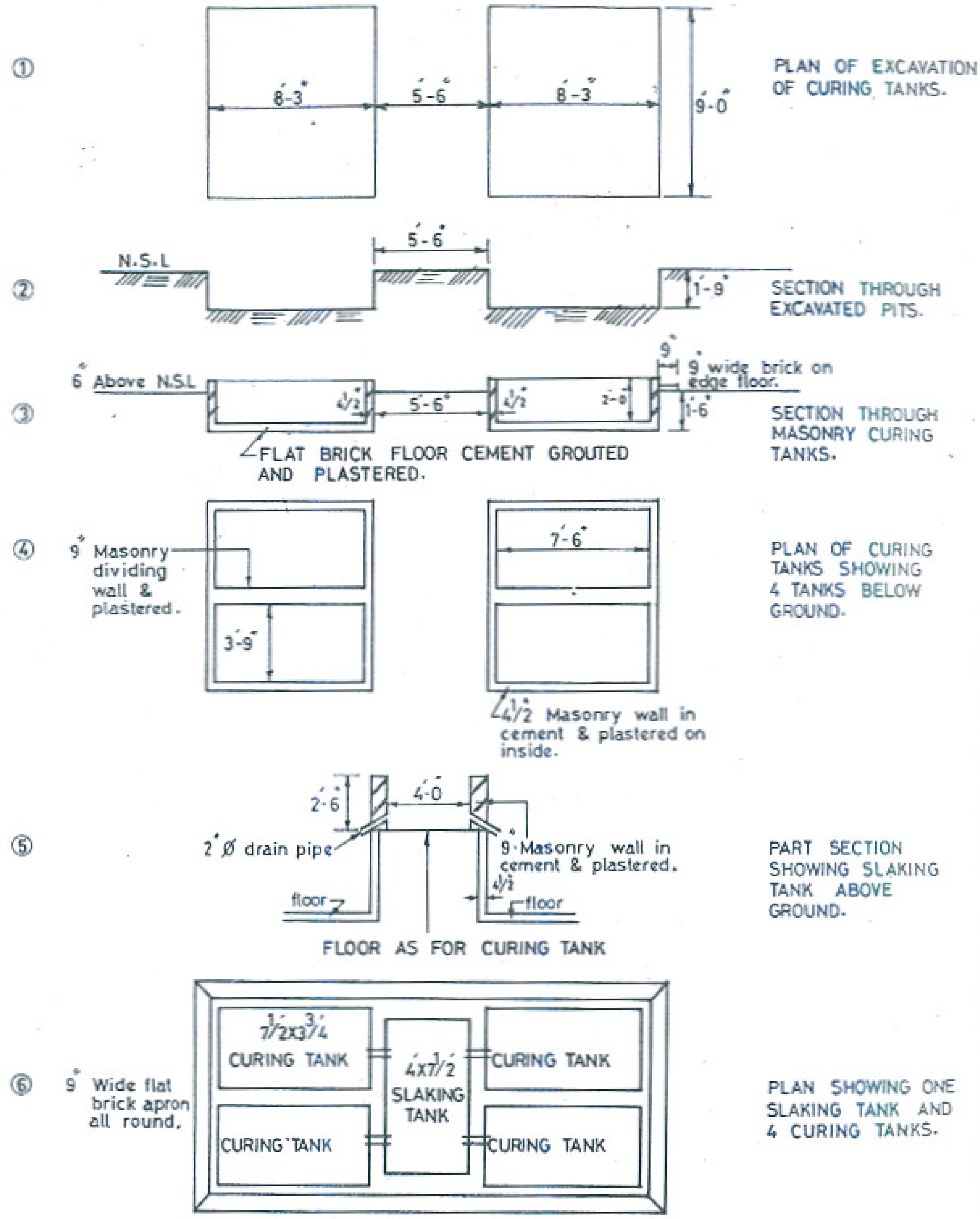
LIME PUTTY

Lime is generally used in putty form (i.e. curd of lime) which is obtained by slaking lime in excess quantity of water about 3 times the volume of lime to be slaked. In order to obtain putty from 40 kg of lime, the tank must be large enough to store 75 gallons of water.A masonry tank plastered internally with cement and having an internal dimension of 3'x 3'x1½' high is convenient to make putty out of 40 kg lime. The tank is filled with water upto a depth of about 1 foot and lump lime (smaller the lumps the better the slaking) is added to water making sure that whole of lime is completely immersed in water. The mixture which will soon become boiling hot,if lime is of good quality, may be stirred with a long wooden stick after every few hours. The mix is allowed to stand overnight and clear water from top is decanted carefully next morning. Fresh water is added to bring the level upto one foot and the whole mass is stirred with wooden rod. The milk of lime is then seived, through, wire gauze screen having 8 meshes per inch, into an adjoining tank so as to remove unburnt/overburnt particles etc. The mix is allowed to stand for a day and top clear water is decanted. The process of adding water and decanting is repeated for another day. The curd of lime left underneath, is called putty which can be used in mortars and plasters in various proportions *by mixing with damp sand or cement sand mixes*. The putty if not allowed to dry, can be used for a week or even two without any danger.

The size of tanks depends on the magnitude of work and the number of masons employed per day. Assuming that two pairs (one I Class and one II Class)of masons employed at a site can lay 150 cft brick masonry per day, the daily requirement of mortar will be about 38 cft, for which 17 cft of lime putty will be needed for 1 : 2 lime mortar and 12 cft putty when 1:3 lime mortar is used. In order to produce 17 cft putty, the size of slaking tank should be sufficient to hold 68 cft of milk. The size of maturing tanks can be reduced as quantity of water need not be three times volume of lime. Since putty is matured for 2 or 3 days before use, it will be better to have 4 curing tanks, two on either side of slaking tank to allow uninterupted construction work at site. The slaking tank is constructed above ground while the four curing tanks are placed below ground, with their walls projecting 6" above ground to prevent rain

FIG I

TYPICAL DETAILS OF SLAKIING & CURING TANKS FOR 17 CFT LIME PUTTY



NOTE

1. A.C Pipe 2" Ø and 1½' long outlets (4 NOs) fitted near the floor of slaking tank to transfer of milk of lime of curing tanks.
2. Slaking tank 4'x7½'x2½' will be sufficient to slake 260 kg lime.

water from draining into the tanks. A typical lay-out of tanks is shown in fig.1.

YIELD OF LIME PUTTY & ITS CONSISTENCY

The volume of putty obtainable from a given weight of quick lime is very important for two major reasons, Firstly, the economics of lime mortar vs cement mortars depend on this yield. Secondly, the mortar is consumed in volume on building site and volume of mortar obtained depends on volume of putty. Mathur estimated a yield of 8 gallons (or 1.28 cft) of putty from 39 lbs of quick lime (or 2.9 cft putty per 40 kg of lime) in India. Even in American, the tests conducted by Emley in 1912 gave a yield varying from 2.2 cft to 4.9 cft per 40 kg of quick lime . In the case of American hydrates, a yield of 1.4 to 2.2 cft of putty was estimated. The tests at BRS Lahore have given 2.69 cft of creamy putty or 2.4 cft of standard putty from 40 kg lime that contained 10 kg (i.e. about 25%) impurities/residue. The yield depends on the quality of lime i.e. lesser the quantity of unburnt/overburnt lime, the higher the yield of putty. Pure quick lime, without impurities, would thus yield 3.2 cft putty in Pakistan. *The local crude country kilns can seldom be expected to give pure lime and hence the need for improving kilns and reducing impurities.*

The yield of putty further depends on the quality of quick lime and on the consistency of putty which is measured on a flow table having a bumping device. When putty spreads from 66 mm to 110 mm with one bump, the consistency is categorized as standard by British & Indian standards, which was followed in the absence of any Pak Standard.

DESIGN CONSIDERATIONS

The strength of brick walls depends not only on the strength of units but also on the strength of mortar besides shape of units.However, the relationship is rather complex; the compressive strength of brick -work is hardly increased by using strong mortar when units having crushing strength of 400 p.s.i. or less are used. On the other hand, when high strength (having crushing value of about 10,000 p.s.i.) units are used, the masonry strength increases with the strength of mortar. But the strength of brick-work is never equal to that of either the unit or the mortar; it is always more than the permissible strength of mortar and less than that of brick unit. These inferences are evident from a glance at the basic stress Table 1 derived from British CP 111 for Load-bearing Brick Walls. In the case of Pakistani bricks, having crushing strength of about 2000 p.s.i. average, the basic strength of masonry varies from 86 to 180 p.s.i. when mortar is changed from 1:3 lime sand (weakest) to 1:3 cement sand (strongest) mix respectively. The basic stress has to be reduced by a factor depending on the slenderness ratio and eccentricity of walls, to work out the permissible stress in a wall and selecting a mortar mix.

Another important factor in design of masonry is that mortar used should have a low linear shrinkage and a high extensibility (linear deformation that a hardened mortar undergoes before failure). Such tests were performed in USA at the National Lime Association in 1920 and it was observed that Lime or Lime-Cement mortars had the highest factor of safety as seen from the Table 2. The cement mortars will be most vulnerable to cracking as compared to cement-lime or lime mortar as has been observed in practice. The greater the proportion of lime, the higher is factor of safety as shown in Table 2.

EXPERIMENTAL WORK

In all, 20 mortar mixes were chosen for investigation covering 7 cement mortars, 11 cement-lime mortars and 2 lime mortars. Ravi sand was used in the investigation for the sake of uniformity. The curing conditions were varied as below for lime/lime-cement mortars to find out effect of curing on strength:-

i) Air curing throughout;

ii) Air cured for first 14 days;

iii) Air cured for 7 days followed by 21 days damp curing;

iv) Damp cured for first 14 days and then air cured;

v) Damp condition for

TABLE 2

FACTOR OF SAFETY AGAINST CRACKING

Mix Ratio			Extensibility (in) per 1000 in	Max.Shrinkage after hardening	Factor of safety
C	L	S			
0	1	3	0.031	0.007	4.43
1	0	3	0.026	0.084	0.31
1	1	6	0.028	0.038	0.74
1	2	9	0.030	0.026	1.16
1	3	12	0.025	0.01	2.5

TABLE 4

MORTAR EQUIVALENCE

Lime Motars				Cement Motars		
C	L	S	Age	C	S	Age
1	1	6	14	1	5	14
1	1	7	14	1	6	14
1	1	8	28	1	7	14
1	2	8	14	1	6½	14
1	2	9	14	1	7½	14
1	2	10	28	1	8	14
1	3	12	28	1	8	14
-	1	2	28	1	7½	14
-	1	3	28	1	8	14

first 7 days and then air cured;

vi) Damp condition for 28 days.

Owing to limited number of moulds, all the experiments could not be conducted on 2" cube moulds and about 50% of tests had to be done on 1" cubes as it was considered to be closer to actual thickness of mortar in practical use. In the present series of tests, lasting about a year starting from October 1978, as many as 1370 cubes of various mixes have been tested, of which 258 comprised of lime-sand mixes, 920 of cement-lime - sand mixes and 192 of cement-sand mixes. The compressive strength of 1" cubes were performed on Hounsefield Tensometer while 2" cubes were crushed in a frame with proving ring, all at ages of 3, 7, 14, 28, 90 and 180 days. The results summarised in Table 3 give average value of all curing conditions, and both sizes of cubes i.e. 2" and 1". All mortars were mixed by volume by hand using standard putty for lime and lime cement mortars. All mortar cubes were made from standard mortars having the prescribed consistency ranging from 65% to 75% for lime or lime-cement mortars and 100% to 115% for cement mortars when tested according to ASTM.

DISCUSSION OF RESULTS

It will be seen from Table 3 that crushing strength of cement mortars is lower than that reported by other Research Institutes. This is primarily due to the fact that Ravi sand having fineness modulus of only 0.89 (grain size between 150 to 300 microns) was used and that a constant water-cement ratio could not be maintained for all cement mortars as the emphasis was to keep the same workability which is the only control exercised at works site. A significant point to note is that the strength of lime mortars after 180 days is increased by 40% to 50% than that of 28 days strength. Furthermore, strength of lime mortars compares favourably with British or American results but higher than Indian results. Emley (1913) concluded that finer the sand, higher the crushing strength. Ninety day strength of 2" cubes of 1 : 2½ by vol) using sand having particle size between 40 and 60 or 60 and 80 mesh was reported by Emley (1913) as 186 and 260 psi respectively. This compares

<u>TABLE 3</u>

CRUSHING STRENGTH OF MORTARS

Mix (by Vol.)			Cube Crushing Strength psi after age of (days)					
C	L	S	3	7	14	28	90	180
0	1	2	51	60	105	123	150	171
0	1	3	34	53	72	90	111	138
1	1	6	151	172	224	353	448	550
1	1	7	68	115	172	277	313	365
1	1	8	50	66	113	148	213	215
1	2	8	58	78	136	154	218	275
1	2	9	50	64	99	130	167	187
1	2	10	41	56	78	110	151	167
1	2	12	31	40	53	83	110	135
1	3	12	31	41	62	77	107	124
1	3	14	26	43	51	69	102	-
1	3	16	26	30	41	60	97	-
1	¼	3	565	813	1030	1323	1470	-
1	0	2	1513	2219	2847	3188	-	-
1	0	3	563	1004	1318	1619	-	-
1	0	4	226	374	403	560	-	-
1	0	5	104	209	277	307	-	-
1	0	6	80	103	182	212	-	-
1	0	7	62	95	113	153	-	-
1	0	8	36	57	63	91	-	-

favourably with results obtained in Lahore with Ravi sand having particle size between 25 and 100 mesh.

Some interesting inferences have been derived from testing of lime mortar cured under different conditions: lime-sand mortars tend to give higher strength when cured in air either throughout or for first 14 days. This should be expected because lime mortars start developing strength after initial drying of water by carbonation from atmospheric Carbon Dioxide. In the case of lime - cement-sand mortars, the strength increased by curing under damp conditions. The old belief that lime retains moisture required for curing of cement and as such curing at works site could be neglected is not confirmed. This finding incidently, corroborates with what was found by Wig & Bates as reported in J.A. Cerm. Soc. of January 1919. Masonry in lime sand mortars does not need much curing by water and that there is no need of soaking the bricks before laying in masonry. The suction of lime milk into the pores of bricks provides the much needed bond and adhesion as confirmed by tests conducted in Australia. The shortage of water at building sites and laziness of labourers to sprinkle water on masonry should therefore suggest use of lime sand mortars instead of cement sand mortars in Pakistan.

The results suggest some approximately equivalence of lime mortars with cement mortars from strength point of view, which is given in Table 4.

The allowable basic stress in masonry for various mortars and varying strength of bricks (derived from British CP 111) as obtainable in Pakistan is given in Table 1 for standard mortars. The strength of masonry in other intermediate mortars may be interpolated for adoption. It is seen that cement lime sand mortars can replace cement sand mortars in majority of masonry works. Lime sand mortars can be used if the basic load on wall does not exceed 120 psi subject to reduction due to slanderness ratio and eccentricity etc. For instance, a double storey school building having 25 ft wide rooms and 12 ft storey height induces a load of about 100 psi at plinth of wall which after applying slenderness factor of 12 is increased to 119 psi which can be sustained by masonry laid in 1 : 2 lime mortar.

The three day strength of lime mortars given in Table 3 indicates that even a weak lime mortar (1:3) is strong enough to sustain a load of 12 ft high masonry (=12 psi) in 3 days. Normally, however, masonry in buildings is seldom raised at a rate more than 4 ft per day and as such there should be no cause for concern on this account.

YIELD AND COST OF MORTARS

The analysis of cost of mortars given in Table 5 shows that lime mortars are cheapest in the present conditions. The analysis is based on very conservative (and safe) estimates of yield of mortars and putty. In the case of lime, 40 kg quick lime has been assumed to give 2.6 cft putty while in actual fact, if the lime is fresh and of good quality, it should yield about 3.2 cft of putty which will tilt the economics in favour of lime and lime-cement mortars still further. As regards yield of mortars, factors like fineness of sand and richness of mix play a significant role. The experiments at BRS Lahore during 1968-70 indicated that yield of mortars depended on the concentration of cement (or/ and lime) in sand. Richer mixes tend to swell more than lean ones and following emperical rule is established :-

Mortar Mix	Volume of sand for 100 cft. wet mortar
a) Cement Sand	
1:2	82
1:3	85
1:4-5	90
1:6-8	100
b) Lime Sand	
1:3	86
1:3	93
c) Cement Lime Sand	
1:1:6	90
1:2:8-9	90
1:3:12	92
1:1:7-8	92
1:2:10-12	94
1:3:14-16	94

The traditional formula of using 120 cft dry ingredients to get 100 cft wet mortar has been found to be misleading and is recommended to be dropped from specifications or schedule.