MAIN FACTORS AFFECTING THE STRENGTH AND DURABILITY OF CONCRETE BRICKS

العوامل الرئيسية المؤثرة على قوة
الطوب الخرساني وتحمله مع الزمن

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خلاصة : نظرا للتباين في نوعيات الطوب الخرساني المستخدم في أعمال الإنشاء - عمل هذا البحث بغرض دراسة خواص الطوب الخرساني المنتج في محافظة الدقهلية - تم اختيار عدد تسعة مصانع بالمحافظة وتم دراسة طرق تصنيع الطوب الخرساني وإجراء مجموعة من الاختبارات على المواد المستخدمة وعينات من الطوب أخذت عشوائيا من كل مصنع لتقييم الخواص الميكانيكية والطبيعية لها - أجريت هذه الاختبارات بمعامل كلية الهندسة / بالمنصورة .

تم عمل دراسة أخرى على عينات من الطوب تم تصنيعها واختبارها لمعرفة تأثير بعض العوامل مثل نسب خلط المواد الداخلة في الخرسانة المستخدمة في صناعة الطوب وطرق المعالجة المختلفة المتبعة في صناعة الطوب الخرساني واستخدام الإضافات وعمر الطوب على قوة مقاومة الطوب للضغط .

ونظرا لاستخدامات الطوب المتعددة أعلى سطح الأرض أو تحت منسوب سطح الأرض ملامسا للتربة فقد تم إجراء مجموعة من الاختبارات لدراسة مقاومة الطوب الخرساني الموضوع تحت تأثير محلول أملاح كبريتات الماغنسيوم بتركيزات مختلفة لمدة ٩٠ يوم - تم في هذه الدراسة استخدام نوع من الإضافات الموجودة في السوق المصري مع عينات من الطوب تم تعريضها لمحلول الكبريتات .

أوضحت النتائج أهمية إجراء الاختبارات المعملية على الطوب للتأكد من صلاحيته للاستخدام المطلوب في المبنى مع مراعاة استخدام الطوب المناسب عند وجود أملاح كبريتات ذائبة في التربة الملامس لها الطوب .

ABSTRACT

This research was carried out to elucidate the status of concrete bricks industry in Dakahelia Governorate. Methods of manufacture of concrete brick followed by different factories were studied. Tests were carried out to evaluate the mechanical and physical properties of the products of the different factories. An experimental investigation was conducted to determine the effect of some factors such as the concrete mix proportions, addition of admixture, curing conditions and age on the strength and durability of concrete bricks. Resistance to sulphate attack of bricks made with additives and without additives was also investigated.

1- INTRODUCTION

Mud and clay were used to produce what was called mud bricks and red bricks which were considered the main building units in Egypt for thousands of years. Mud and clay were brought from the River Nile or through the excavation of the agricultural land. After the High Dam was built, the amount of mud brought by the River Nile decreased. The population in the other hand tremendously increased and the available agricultural land is very limited. However, the excavation of the agricultural land and the production of the red bricks was prohibited by law. Production of other type of bricks as alternatives of the red bricks as a building units were of a must to achieve the demands of the construction sector. Accordingly the other types of bricks such as sand bricks, sand-lime bricks, light weight sand-lime bricks, shale bricks, light expanded clay bricks (LECA), Gypsum blocks and concrete bricks and blocks were the alternatives. Contractors and owners preferred the concrete bricks because the cost is somewhat lower than the other types of bricks. Concrete bricks and blocks extensively produced in the private sectors in Dakahelia Governorate. Different qualities of concrete bricks are produced. The concrete bricks are used in non-load bearing walls and in load bearing walls. Evaluation of the products of the different factories to determine their qualities is of great importance. In the other hand, research work aiming to improve the strength and durability was greatly welcomed by manufacturers. Brick works exposed to aggressive conditions such as soluble salts and other chemicals may be existed in structures in direct contact with the soil in the agricultural areas or in cities. Moreover, strength and durability are very close characteristics which greatly depend on the properties of the used materials, their proportions, mixing, moulding compaction and curing. The surrounding conditions in which the bricks would be used should be taken into consideration in manufacture and protection of these bricks for the sake of their durability.

2- Manufacture of Concrete Bricks

Stationary and movable brick producing machines are used either in factories or in building sites (Fig. 1-4). Contractors sometimes use small brick producing machines in building sites for economic considerations regarding the amount of bricks needed, the transportation costs and time saving. In this case, very simple operating machines are used which need a very short training before their usage into action.

Big stationary brick producing machines are often provided with concrete batch plants where batching and mixing are carried out mechanically (Fig. 5). Casting and moulding are usually followed by compaction through vibration and compression. Bricks are usually transported to curing stage by either steam curing or curing with water sprinkling in open area (Fig. 6-7).

The movable brick producing machines commonly known as "egg laying machines" are usually fed with the concrete mix in batches. Fixed moulds are provided as a part of these machines. These moulds are filled with concrete and by tamping the concrete blocks are placed at the ground and the machine keeps moving. Curing is usually carried out by water sprinkling. In most cases, concrete bricks are not shaded from sun rays after casting which greatly affects its strength and durability (Fig. 7).

The third type of brick producing machines used in construction sites consist of moulds fixed to these machines which are filled manually with concrete mix. Compaction is carried out by tamping through a steel table about waist height supporting two or more moulds (Fig. 4). After moulding the bricks are removed to storage area and cured by water sprinkling for a short period followed by air- curing till the date of usage (Figs. 8 and 9).

The use of different types of bricks producing machines, curing method and the skills of the labours are the major factors in this industry that affect the quality and uniformity of the production.

3- Factories Under Investigation

Five concrete bricks producing factories were taken into consideration in the research study to evaluate the situation of this industry in Dakahelia Governorate. These factories are the main suppliers of concrete bricks to the construction sector in this Governorate. The five factories chosen lie in Mansoura city, Belkas town, Sandoup town, Nawase village and Basendela village. Four factories of them produce concrete bricks using movable egg laying machines and the fifth factory uses a stationary producing machines (table 1).

4- Experimental Work

Two groups of tests were carried out in this research, the first group was carried out aiming to evaluate the real production of the factories. The second group was carried out to investigate through research scheme the factors affecting the strength and durability of cement concrete bricks.

The first group of tests was undertaken on samples of the materials obtained from the five factories considered in this research. The materials were taken and tested according to the Egyptian standard specifications (1-4). Concrete mix proportions was also recorded as well as the method of manufacture. Samples of the brick produced in each factory were taken and tested to determine their mechanical and physical properties (table 1).

The second group of tests was undertaken on a controlled samples made in a site adjacent to the Faculty of Engineering, Mansoura University (during time of erecting laboratories building) using a small brick egg laying machine (belong to the contractor). The concrete mix proportions chosen in the controlled samples were as that used by most of the brick factories. The ratio of coarse to fine aggregates was 2 to 1 and the amount of cement was 250 kg/m^3 of concrete. Water/cement ratio was about 0.38 which gave a dry concrete mix suitable to this type of machine. Each of the concrete mix was varied according to the study program. Brick size used was 25x12x6 cm.

The materials used were sand, crushed limestone, Ordinary Portland Cement, tap water and a superplasticizer commercially available in Egyptian market. Tables 2 (a and b) show the grading of the sand and coarse aggregates.

The test program was planned to study the effect of some factors such as cement content, methods of curing adopted by the manufacturers and age on concrete bricks. Resistance to sulphate attack of bricks made with additives and without additives was also investigated. Tests were undertaken in laboratories of the faculty of engineering, Mansoura university.

5- Analysis and Discussion of Test Results

5-1 The Current Production of the Factories

About five hundreds of concrete bricks were taken in different periods through the time of proceeding this research from the factories under investigation. The bricks were taken at random without any selection and tested in the laboratory. Table (1) shows the different mechanical and physical properties of these bricks.

5-1-1 Bricks Compressive Strength

It can be seen in Table (1) and Fig. (10) that the average bricks compressive strength obtained from the five factories ranged between 45 kg/cm^2 and 142 kg/cm^2. The standard deviation ranged between 7 and 16.6 kg/cm^2 and the coefficient of variation ranged between 70 and 166. These differences in the properties of the bricks greatly affect the quality of the brick works. Differences are more obvious in the factories using egg laying machines. The statistical properties (mean, standard deviation, and the coefficient of variance) computed for the five factories were statistically analyzed. The results are shown in table (1). It can be seen that the average compressive strength out of the five factories was 100.2 kg/cm^2, the standard deviation 32.33 kg/cm^2 and the coefficient of variation 646.6%. These results show the great difference in the properties of the production of the different factories.

From the site of observations of the technique followed in manufacture of cement bricks, it can be concluded that many factors are behind the great variation in the above test results among which are water/cement ratio and the applied pressure. These two factors are directly related to the concrete bricks manufacture.

5-1-1-1 Water/Cement Ratios

The amount of water added to the concrete mix used in manufacture of bricks is usually chosen to produce dry and loose mix which can flow easily from the hopper into the moulds and achieve high strength after hardening. Consequently, The production is of a some-what an open textured mass, having a rather lower density than that associated with concrete. Applied pressure during moulding is essential to achieve dense concrete bricks. However structural concrete normally has a density of about 2300 kg/m3 while concrete bricks have an average density of about 2000 kg/m3.

5-1-1-2 Applied Pressure during Moulding

In case of concrete bricks cast in construction sites, moulds are filled manually and a vertical bars with end plate is dropped down sharply to strike the concrete mix in the moulds and compact it. Two or three strikes are usually applied to achieve sufficient compaction.

In big concrete brick producing factories, compaction of concrete bricks is usually carried out through vibration and high pressure by means of hydraulic press. Both the vibrating process and the applied pressure should be controlled so that no segregation occurs and the stripping of the forms faces no difficulties. Increasing time of vibration and/or the applied pressure than the optimum recorded for the producing machine would result in defected bricks of low strength and improper shape.

In comparison with egg laying movable machines and small size portable machines, the big stationary machines produce concrete bricks of higher quality.This might be refered to the high control during batching, mixing and compaction.

5-2 Experimental Study

5-2-1 Effect of Cement Content

Table (3) and figure (11) show the compressive strength test results of concrete bricks at 7 and 28 days age. It was found that brick compressive strength increases with the increase of the cement content in concrete mix. The relation between the strength and the cement content within the range taken in this study was almost linear. However, increasing the cement content should be limited due to the economic consideration and the reverse action due to the high shrinkage at high cement contents which might cause fine cracks. The factories taken into consideration in this study use a cement content of 200 and 250 kg/m^3 of concrete.

5-2-2 Effect of Method of Curing

Four curing methods were adopted in this research work including open air curing without shading, open air curing with shading, open air curing with shading and sprinkling with water twice a day and finally curing by immersion in water tanks.

Table (4) shows compressive strength of test results of those specimen tested at 28 days age after exposure to different methods of curing. The highest compressive strength was recorded for those specimens cured in water and the lowest strength was recorded for those specimens left in the open air without shading. In comparison with those bricks left in the open air without shading, shading the bricks increased its strength by about 12% while sprinkling with water has increased the strength of shaded bricks by about 30%. The gain in strength for concrete bricks placed in open shade and sprinkled with water was about 21% in comparison with those left in open shade without curing.

It is clear that curing method is a vital factor greatly affects the strength of the concrete bricks. Water curing helps in the completion of the hydration process minimizes the evaporation of mixing water due to the surrounding atmosphere and the high temperature during the hydration process. Exposure to the open air and direct sun rays without shading accelerates the rate of evaporation of the free water from the green concrete producing voids and hair cracks in the concrete bricks and consequently decreases their strength.

5-2-3 Effect of Age

Concrete bricks produced in construction sites are usually used at the age of 3 to 4 days after casting. In big factories bricks usually stored for 7 days after casting before they will be transferred to construction sites.

Table (5) and figure (12) show the effect of age on the concrete bricks compressive strength. Bricks were manufactured using a simple egg laying brick producing machine. Bricks were stored in a shaded place and cured by water sprinkling twice daily. The compressive strength of bricks 3 to 7 days age were about 43% and 72% of that recorded at 28 days age respectively.

5-2-4 Effect of Sulphate Salts

To determine the effect of water reducing admixtures on the compressive strength and sulphate resistance of concrete bricks two concrete mixes were cast. The first mix contained no admixtures while in the second mix a water reducing admixture available in the Egyptian market was used. After casting and compacting using a simple egg laying brick producing machine the bricks were divided into two groups. The first group was immersed in tap water, while, the second group was immersed in a magnesium sulphate solutions with concentration of 4 gm/lit and 8 gm/lit for 90 days.

Table (6) and figure (13) show that brick compressive strength decreased after exposure to magnesium sulphate solutions for 90 days in comparison with those exposed to tap water. The reduction increased with the increase of the concentration of the sulphate solution. Reduction in strength of 44% and 51% were recorded for those specimens immersed in sulphate solutions with 4 mg/lit and 8 mg/lit respectively in comparison with those immersed in tap water. These figures were 7.5% and 19% respectively for bricks made of concrete mix containing a water reducing admixture.

It is well known that the tricalcium aluminate existed in Ordinary Portland cement can react with sulphate solution to form a compound called calcium sulphoaluminate or "ettringate". The reaction is usually accompanied by expansion of the cement paste. When it occurs in concrete bricks or brick work mortars, it greatly affects the overall expansion of the brick work. This could later cause disintegration in mortar layer bonding brick layers together. However, to proceed the harmful effect of sulphate, three components have to be existed which are tricalcium aluminate, soluble sulphate and water. These components might be available in concrete bricks as well as surrounding environment. Foundations, retaining walls and all structural members in contact with contaminated soils containing sulphate salts are exposed to the attack of such salts. High quality concrete bricks with special protection should be used. Blast furnace slag cement or sulphate resistance cement are recommended (9). Water reducing admixtures proved to have high resistance to the effect of salts.

6- Conclusions

With regard to the results obtained from the above research study and the available collected data from five brick factories around Mansoura city, it can be concluded that;

1. There are great differences in the concrete bricks properties produced in the different factories considered in this research and

even in the production of the same factory.

2. Bricks compressive strength ranged between 45 kg/cm^2 and 142 kg/cm^2. This great differences implies testing of the bricks before usage in the construction to insure the suitability of the used bricks for the construction purpose.
3. Most factories considered in the research study used cement content 250 kg/m^3 in the concrete mix. This value was chosen to achieve reasonable strength and shrinkage with the minimum cost.
4. Factories contain machine with high control during batching, mixing and compaction produce concrete bricks of better quality and uniformity.
5. Although curing of concrete bricks has great effect on their strength, it is not given enough consideration in bricks manufacture particularly those produced in building site. Shading the concrete bricks and sprinkling with water for a reasonable time may increase the compressive strength of the product by 30% than the bricks left to dry in open air.
6. It is recommended not to use bricks in the construction work before seven days after casting.
7. In case of using concrete bricks in places containing sulphate salts in wet surrounding environment, it is preferred to use a special concrete bricks manufactured with blast furnace slag cement or sulphate resistance cement. Also, in the mortar used with bricks should be made of the same type of cement.

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Table (1) Mix Proportion, brick compression strength, absorption and unit weight of brick samples (Average of 10 bricks)

Location	Machine	Mix. Proportion	Comp. Str. kg/cm^2	Absorption %	Unit weight kg
1-Sandoup	Egg-Laying	C 200 kg S 400 kg Cr.L.S. 925 kg W 150 lt	Av. 91.5 σ 11.17 V 111.7%	7.85	3.4
2-Nawasa	Stationary	C 250 kg S 0.4 m^3 Cr.L.S. 0.8 m^3 W 170 lt	Av. 117.5 σ 7.0 V 70.0%	7.25	4.4
3-Belkaas	Egg-Laying	C 250 kg S 0.5 m^3 Cr.L.S. 1.0 m^3 W 180 lt	Av. 44.6 σ 9.4 V 94.0%	7.47	3.46
4-Nawasa El-Bahr	Egg-Laying	C 80 kg S 200 kg Cr.D.S. 600 kg W 60 lt	Av. 141.8 σ 16.6 V 166.0%	5.12	3.67
5-Bacendla	Egg-Laying	C 250 kg S 0.5 m^3 Cr.L.S. 1.0 m^3 W 180 lt	Av. 105.8 σ 13.7 V 137.0%	7.34	3.74

C = cement
S = sand
cr. L.S. = Crushed lime stone
cr. D.S. = crushed Dolomite stone
W = water
Av = Average
σ = standard deviation
V = coefficient of variation

$\overline{Av}$ = 100.2 kg/cm^2
$\overline{\sigma}$ = 32.33 kg/cm^2
$\overline{V}$ = 646.6 %

Table (2) Fine and coarse aggregates grading
a) Sand

Factory location	% Passing				
	Sieve (mm) 2.83	1.41	0.707	0.354	0.177
1- Sandoup	100	63	16.8	2.1	1.0
2- Nawasa	100	97	50.4	16.2	6.2
3- Belkaas	100	97.2	27.7	5.5	2.7
4- Nawasa El-Bahr	100	99.0	71.2	25.0	8.0
5- Bacendela	100	98.1	57.1	14.6	4 7

b) Coarse aggregate

Factory location	% Passing			
	Sieve (mm) 19	9.51	4.76	2.83
1- Sandoup	100	75.3	19.3	11.9
2- Nawasa	100	55.6	12.4	3.8
3- Belkaas	100	28.4	1.1	0.6
4- Nawasa El-Baher	100	50.1	13.4	4.8
5- Bacendela	100	74 9	17.8	7.4

Table (3) Effect of cement content proportion on bricks compressive strength.

Cement Content kg/m^3	Compressive Strength at 7 days kg/cm^2	Compressive Strength at 28 days kg/cm^2
100	32	41
150	35	46
200	66	81
250	97	127
300	130	178

Table (4) Effect of Method of curing on bricks compressive strength at 28 days

Method of curing	Compressive strength (average 5 bricks)
1. Placed in open air without shade, uncured with water.	82 kg/cm2
2. Placed in open shade, uncured with water.	93 kg/cm2
3 Placed in open shade, damped twice daily	118 kg/cm2
4 Placed in water tank, (reference)	147 kg/cm2

Table (5) Effect of age on concrete bricks compressive strength

Age	Compressive strength (average 5 bricks)
24 hours	23 kg/cm2
3 days	48 kg/cm2
7 days	80 kg/cm2
14 days	86 kg /cm2
28 days	111 kg/cm2

Table (6) Effect of sulphate solution on concrete bricks compressive strength cured in solution for 90 days.

Curring Media	Compressive Strength (Average of 5 Bricks) Kg/cm^2	
	Without Additives	With Additives
1. Magnesium Sulphate solution		
4 gr/L	103	197
8 gr/L	91	172
2 Tap Water (reference)	187	213

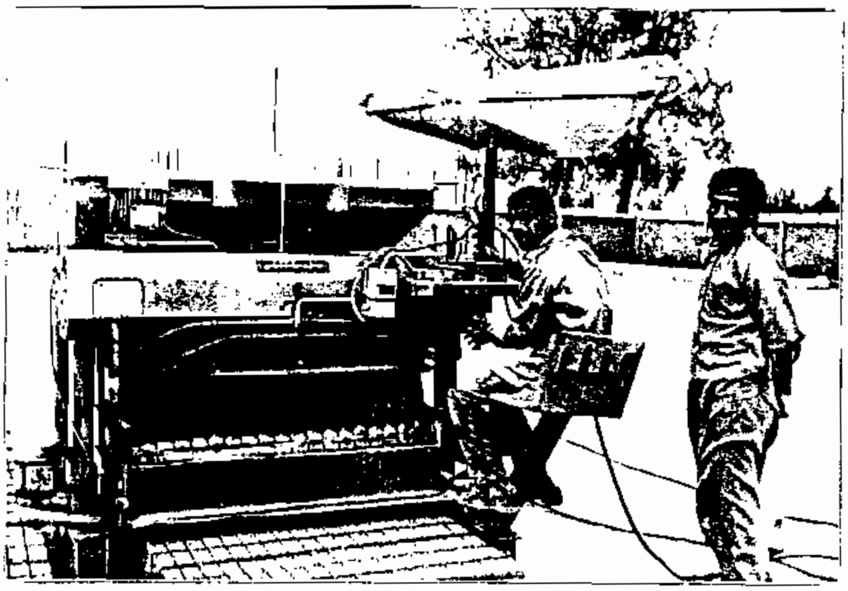

Fig. (1) Movable Concrete Brick Producing Machine (Big Size).

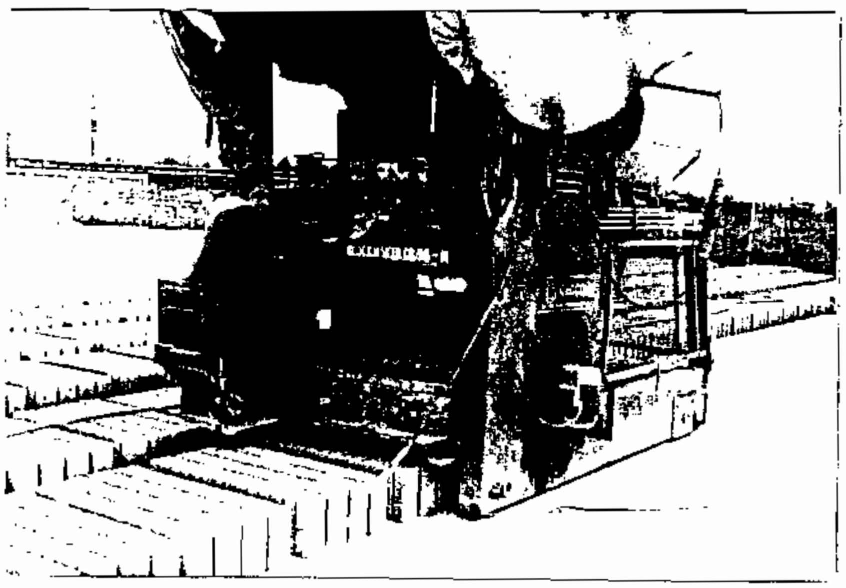

Fig. (2) Movable Concrete Brick Producing Machine (Medium Size).

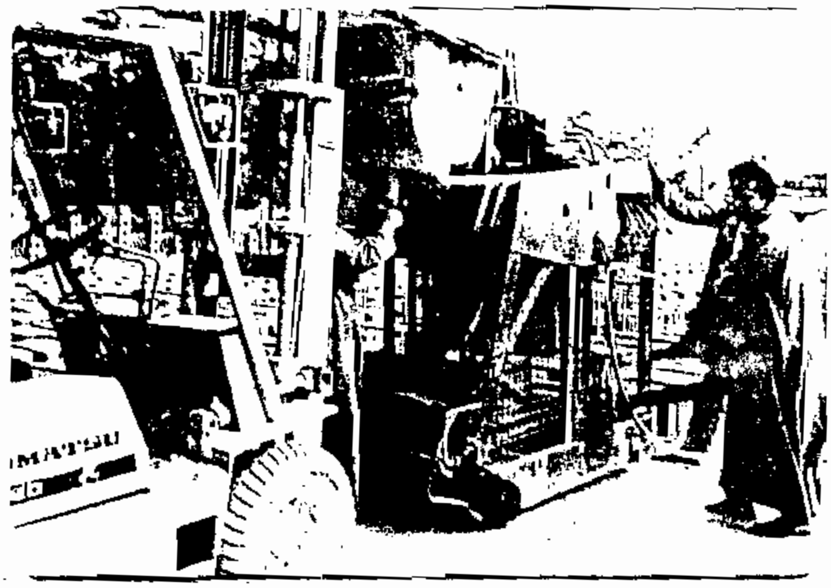

Fig. (3) Movable Concrete Brick Producing Machine (Small Size).

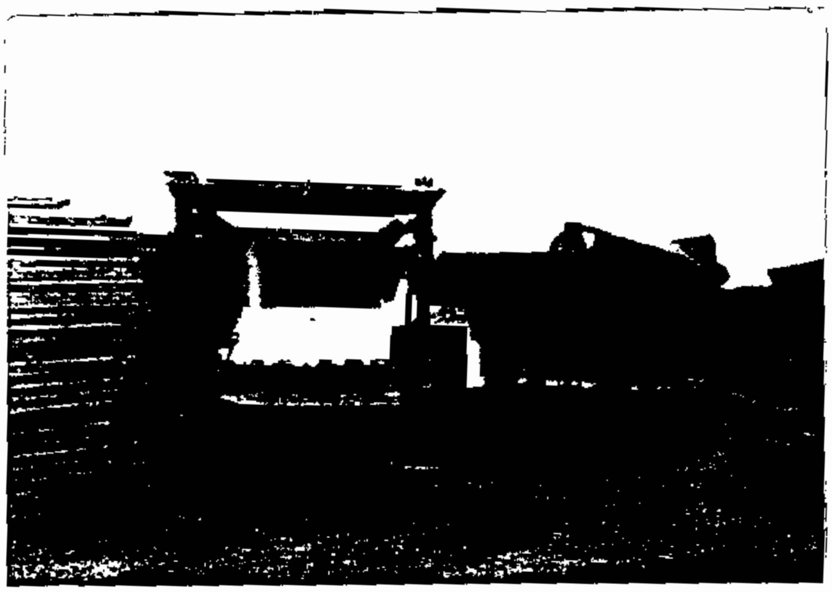

Fig. (4) Single Stationary Brick Producing Machine.

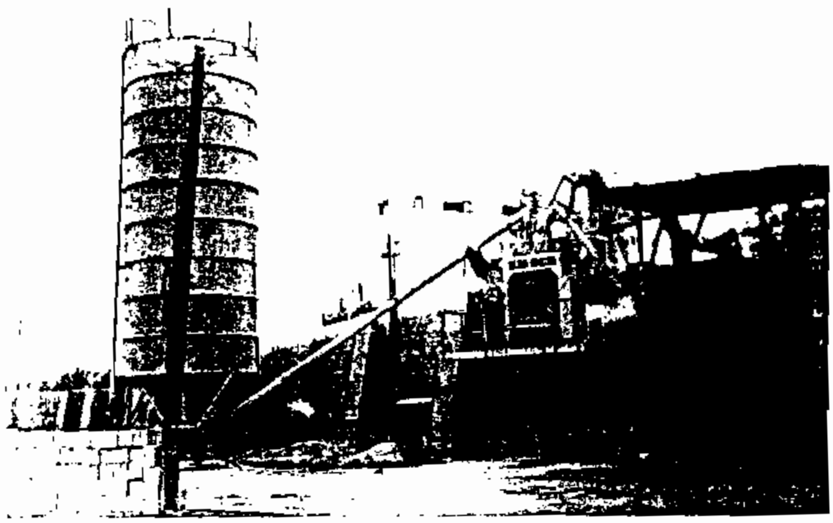

Fig. (5) Batch Plant in a Concrete Brick Factory.

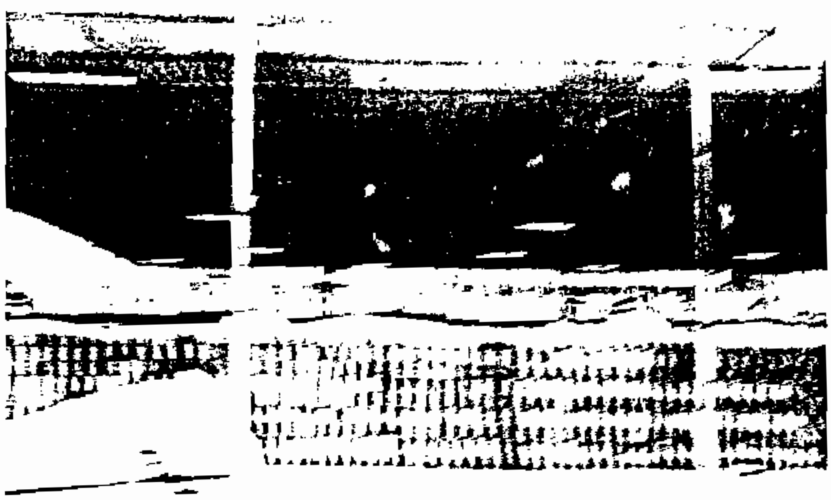

Fig. (6) Shaded Production in a Concrete Brick Factory.

Fig. (7) Unshaded Production in a Concrete Laid Factory.

Fig. (8) Mixing Manually in Making Bricks in a Building Site.

Fig. (9) Concrete Bricks Manufactured in a Building Site.

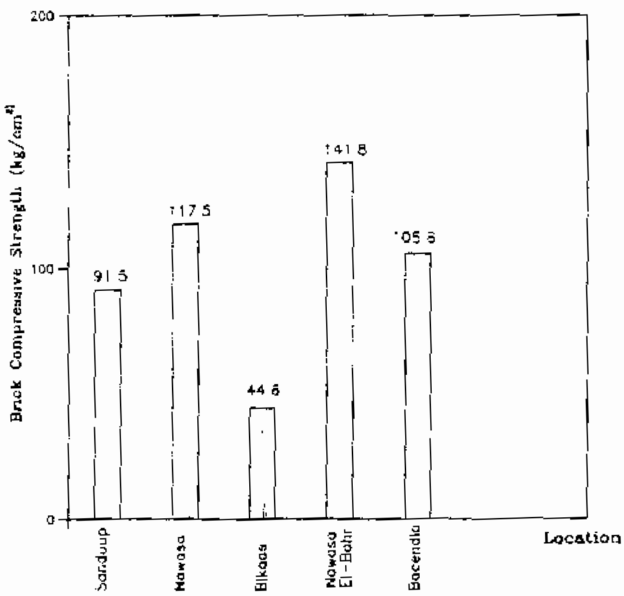

Fig. (10) Brick Compressive Strength of the Current Production in the Five Factories considered in the Study (Average of 10 Bricks).

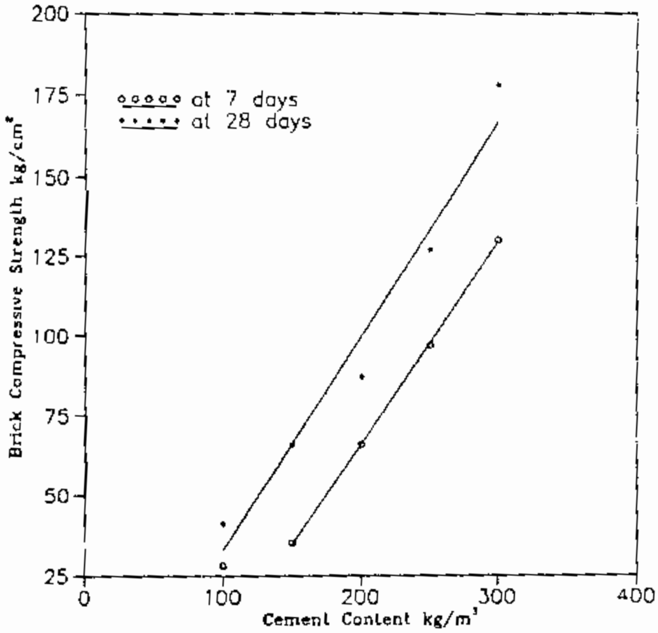

Fig. (11) Effect of Cement Content on Brciks Compressive Strength.

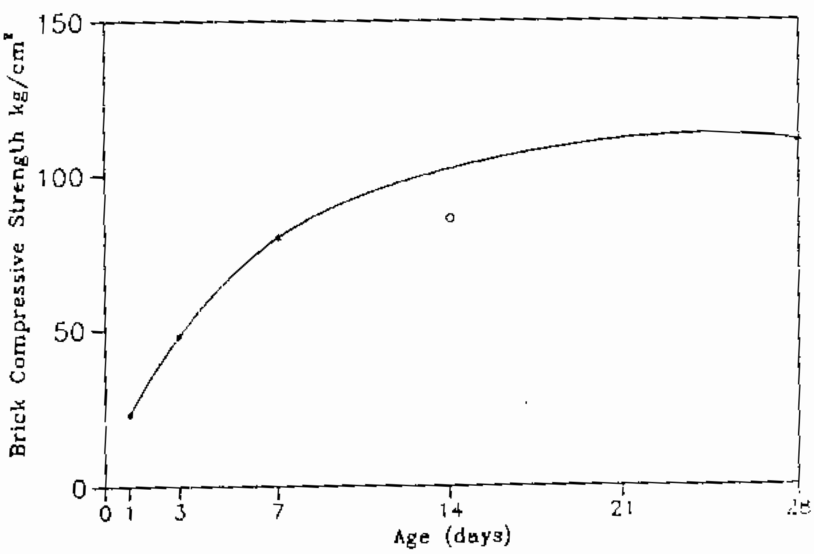

Fig. (12) Effect of Age on Concrete Bricks Compressive Strength.

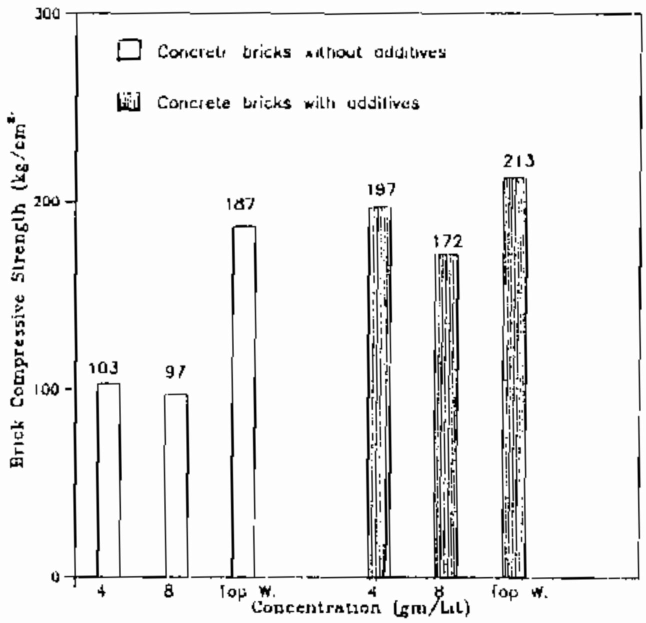

Fig. (13) Effect of Sulphate Soution on Bricks Compressive Strength.