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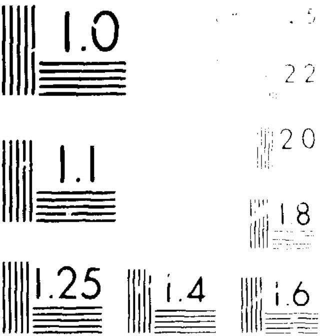
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ASSISTANCE TO THE DEVELOPMENT OF THE CONSTRUCTION AND BUILDING MATERIALS INDUSTRIES

DP/SYR/80/001/

SYRIAN ARAB REPUBLIC

TERMINAL REPORT

Prepared for the Government of the Syrian Arab Republic by the United Nations Industrial Development Organization, executing Agency for the United Nations Development Programme.

BASED ON THE WORK OF J.E. UJHELYI
ADVISER IN POZZOLANIC AND LIGHTWEIGHT MATERIALS

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
VIENNA

Explanatory Notes

Value of the local currency during the period of the project was : 5,?0 Syrian Pounds for 1 US Dollar

Throught the report the following abbreviations are used:

G.O.C. : for General Organization for Cement and Building Materials Industry, Government Implementing Agency in the Project

L.M.C. : for laboratory of Ministry of Communication

I.T.R. : for Industrial Testing, Research and Development Centre.

ABSTRACT

Title of the project, Assistance to the development of the Construction and Building Industry

Number of the Project: DP/SYR/80/001/11-03/32.1.K

Purpose of the project: Evaluation of the possibilities of using volcanic materials in the building industry for

- production of pozzolanic (blended) cement
- production of hydraulic lime
- production of lightweight aggregate concretes.

Objective of the mission: carrying out investigations with pozzolanic materials (details in Annex 1).

Duration of the mission: 2 August - 31 October 1981 (in Damascus: 5 August - 28 October 1981).

Main conclusions and recommendations: It can definitely be stated, that many volcanic materials are available in the Syrian Arab Reppblic to produce blended cement, hydraulic lime and lightweight aggregate concretes, but their qualities are not thoroughly investigated.
Expert began to investigate the materials suitable for hydraulic lime and lightweight aggregate concrete and to train a few collaborators in G.O.C., L.M.C. and I.T.R. but these investigations were only the first steps to clear the most important properties of the materials (details in Annex 2,3&4).

Expert sketched the detailed program of the investigations (Annex 4). According to this work schedule, the research work can last about six months for a single type of the aggregates. Expert recommended three alternatives for the performance:

a) The research work can be ordered from a foreign Research Institute well equipped and possessing experiences in the field of volcanic materials:

b) One collaborator of G.O.C. can be sent to foreign fellowship for training of duration of six months and this collaborator will continue the investigations begun:

c) The project can be extended with duration of one year and one UNIDO expert shall be selected for the post, the goal of which to carry out the investigations according to Annex 4.

Nevertheless, the investigations can start in Damascus only after equipping I.T.R. with suitable instruments, machines, etc for carrying out concrete research work.

TABLE OF CONTENTS

4/...

5/...

INTRODUCTION

Abundant raw materials for various building materials industries exist in many parts of the Syrian Arab Republic. Except for the existing cement works and their extensions under execution, the other building materials industries are not adequately developed so far. The production of lime, gypsum, plaster and prefabricated building blocks are known on a small scale, dispersed manufacturing processes, whereby the quantities and qualities are not organized on economic industrial standards. There is an intention to introduce some of the most important building materials industries, with ambition targets involving wide dispersal of these industries over the widest possible areas all over the country, taking into consideration that long transportation of most building materials is not in favour of constructional economics.

This situation created the need for technical assistance for the development of new building materials industries according to priorities imposed by raw material resources and long term requirements for building materials.

More reports were prepared in the last few years (enumerated in Annex 1, Chapter 4). Three of them are important in the relation to the topic of this report: made by Mr. Bozanovic (1978) by Mr. Prijic (in 1980) and by Mr. Kepinsky (in 1981).

Mr. Bozanovic suggested to establish research laboratory for investigation of every building material, including concrete. Mr. Prijic performed investigatinns for making blended cement with ground volcanic materials. Mr. Kepinski worked out the industrialization possibilities of concrete products. These reports made unnecessary for the expert to deal with blended cement as well as with prefabrication of concrete units in general. This work, therefore, could be limited to the problems of hydraulic lime and of lightweight aggregate concrete.

The assistance was requested from the Syrian Government on August 1981 and approved by the UNDP. The expert was selected to the post on 10 March 1981, the project was begun on 2 August 1981 and lasted to 31 October 1981.

The co-operating agency (Government Implementing Agency) was the General Organization for Cement and Building Materials Industry.

The total contribution of UNDP, according to the Project Document comes to 133600 US Dollars and the UNDP's contribution to the mission reported was 14 400 US Dollars.

The original objectives of this mission, according to the Project Document and Job Description were:

- the geological surveying of volcanic materials deposits,
- assessment of available data already revealed, conducting the performance of further physical and chemical investigations, proposal for further research work,
- proposal for quarrying and industrial processes and rational application for the materials,
- evaluation of binding properties for pozzolanic materials,
- special study devoted to porous pozzolans for lightweight aggregate concretes,
- study of possibilities for application of pozzolanic materials for the production of precast concrete elements and
- practical demonstration of possibilities for the utilization of coloured pozzolans in concrete work for plastering facades

These objectives were revised at the first discussions with the Government Implementing Agency (G.O.C.). The reason of revising are as follows:

a) The Syrian Government gives priority to further research work for testing volcanic materials derived from different regions.
b) The Syrian Government is keenly interested in development of prefabricated concrete, therefore it gives priority to the lightweight aggregate concretes in the further research work.
c) The Syrian Government is also interested in making hydraulic lime with pozzolanic materials for rendering mortars on surfaces of inner and outer walls.
d) The Syrian Government is presently not interested in production of blended cement, rather it considers the investigation up till now to be sufficient.

8/...

According to the above, the mission was primarily concentrated for the investigation of producing lightweight aggregate concretes and hydraulic lime.
The results of these investigations are reported in Annex 3 & 5.
There were no formal training arrangements, but on the job training took place in L.M.C. (with participation of one geologist from G.O.C., furthermore one geologist and one technician from L.M.C.) in the field of lightweight aggregate concrete investigations and later in I.T.R. (with participation of one geologist from G.O.C. as well as one technician and one laborant from I.T.R.) in the field of pozzolanic activity investigations.

The positive result of this on the job training was that the adviser could introduce the counterpart in problems and methods of investigation. This training was not; however, fully efficient because the available equipments, instruments did not make the exact research work possible (in the L.M.C. there are no crusher screener, mixer and compacting machine) and the progress of the research work was very slow owing to the insufficient moulds (only eight cylinders were available). It was impossible to ensure the required accuracy in grading, mixture, mixing and compacting.

Nevertheless, the results of the investigations make the evaluation possible and the adviser, being supported by his experiences of more decades, can assume the scientific responsibility for his presumptions.

R E C O M M E N D A T I O N S

1.- The investigated volcanic materials are suitable for making lightweight aggregate concretes of different qualities, therefore their quarrying and utilizing in the building industry can be taken in account. Methods of quarrying can be established by controlling the uniformity of the rock quality in all the volcanic deposits, whose locations are suitable for quarrying (water, electricity and road are available).

Primarily the materials of each deposit should be classified by ocular estimate according to their colour, density, surface structure, granularity, etc. and from each class of material, samples of a few kgs (5-10 kgs) should be taken.

9/...

The samples should be investigated in laboratory (specific gravity, unit weight and crushability of the rock, further more the bulk density and strength of particles from the crushed material). For crushing, jaw crusher in laboratory scale is advisable.

The uniformity of material in one deposit can be evaluated by mathematical statistical analysis. If the standard deviation of above properties (that of the bulk density and strength primarily) less than 20 pct (variation coefficient), selective quarrying is not necessary. If the standard deviation is more than 20 pct, material of suitable uniformity for producing lightweight aggregate concrete can be obtained by selective quarrying only.

2.- Because of the satisfactory properties of the tested materials, it can be recommended to continue the investigations also with materials of the other volcanic territories which are near to the most important districts signed for development. The materials of other deposits shall be classified according to the above.

3.- After having classified materials of deposits in Shahba, Racca and Hassake, from the different groups of quality samples about 5-5m^3 in volume should be taken for detailed laboratory investigations (see Annex 4, Chapter 3.22, 3.23 and 3.24). The rock should be crushed, the crusher employed depends on the results of crushability's investigations; if the fine grains quantity was less than 30 pct after crushing in jaw crusher of laboratory scale, for crushing rock, hammer or giratory crusher can be employed. If the fine grains quantity was equal to about 30 pct, jaw crusher can be used to produce aggregate. If the fine grains quantity was higher than 30 pct in the laboratory crusher, roller can be suggested for crushing big sample.

4.- It can be recommended to carry out the investigations in Damascus at I.T.R. For the time being, I.T.R. is not equipped for concrete research work, the Syrian Arab Republic, however, is not to be dispensed with suitable laboratory for investigating every building material.

The necessary instruments, machines, etc., are detailed in the Report of Mr. Bozanovic, but the laboratory has to be completed with jaw crusher in laboratory scale, instruments for investigating aggregate strength, creep of concrete, moulds of different sizes; etc.
When the laborotary for concrete research work is equipped the investigations can only be started and carried out either by Syrian collaborators or by UNIDO adviser.
If the utilization of volcanic materials is urgent for the Syrian building industry, foreign research institute can be commissioned to carry out the necessary investigations.

5.- If the investigations will be carried out by Syrian collaborators, training is needed in a foreign Research Institute which has experiences in lightweight aggregate concrete. For this foreign fellowship, duration of six months can be recommended.

6.- If the investigations will be carried out by UNIDO adviser, preparation of job description can be recommended. The job description has to contain the requirements for investigations both of rock uniformity and technology. For this job, duration of twelve months can be taken in account.

7.- If the investigations will be carried out by foreign Institute preparation of calling tender can be suggested. The calling tender can be recommended to send out primarily to research institutes in Europe (Bulgaria, Denmark, England, G.D.R., G.F.R., Greece, Hungary, Poland and U.S.S.R. have research institutes having experiences in lightweight aggregate concretes).

8.- The investigated materials can be utilized, in all likelihood, as follows:

- material of Shahba is suitable to make thermal insulating and load bearing (i.e. intermediate) concrete. It can be expected unit weight of 100-1400 kg/m^3 and compressive strength up to 10 MPa.

For making aggregate, crushing is not necessary. The grading of the original material is not satisfactory, therefore it has to be completed with natural fine sand (0-1mm) if the required strength is more than 5 MPa.

- Materials of Hassake and Racca are suitable to make load bearing concretes with compressive strength up to 25 MPa and with unit weight up to 1900 kg/m^3 (dry unit weight). For making aggregate of suitable grading, using jaw crusher or hammer will be probably necessary.
  In the Syrian Arab Republic making concrete walls is in general use but it dissatisfies the comfort conditions, the temperature sensation in the rooms is disagreeable owing to the cold walls in the cooler seasons. Therefore it can highly be recommended to displace ordinary concrete walls by lightweight concrete ones.
  For technology of production of lightweight concrete walls, the following methods can be recommended:
  - making masonry units (sizes e.g. 30x20x20cm) in machines which compact the concrete by vibrating under pressure of 0,1-1 N/mm^2 (so called: vibropress). These machines are available together with cement and aggregate silos, with balance for dosage, with mixer and with transportation facilities for the fresh masonry units,
  - making elements of medium or big sizes (e.g. 150x90x20 cm or 300x90x20 cm) in moulds equipped with outer vibrators which compact the concrete only by vibrating and after compacting, the moulds can be taken of from the fresh concrete. The fresh concrete has enough cohesivity to take a firm stand. These vibrating moulds can be available together with silos, balance mixer and transportation facilities.

9.- For making hydraulic lime, primarily the materials of Racca and Shahba can be recommended, the material of Hassake, however, has also hydraulic activity. The raw material must be ground to minimum 3000 cm^2/g in specific surface and mixed with hydrated lime of about 40 pct by weight and with plaster (of Paris) of 3 pct by weight.

The binders are suitable for making rendering and plastering mortar.

1.- The materials investigated can be employed in the Syrian building industry in a suitable and economic way only, if the Code Practice of their utilization to lightweight, concrete and rendering mortar are prepared.
The preparing Code Practice, detailed investigations are recommended according to the Recommendation 4.

ACKNOWLEDGMENTS

The adviser is most grateful to Mr. Hani Nabulsi, Director of Studies in General Organization for Cement and Building Materials Industry for his effective help done by the appropriate preparation of adviser's activity and the fruitful discussions during his mission. He is also most grateful to Mr. Hisham Sharafly, General Director of Industrial Testing, Research and Developing Centre and to Mr. Marwan Sati, Director of the Laboratory in Ministry of Communication for their effective promotion in the investigations.

The adviser thanks the help of Mr. Mohamed Shahib for the excellent work in collecting samples of materials and making the administration of the adviser's activity possible.

Last but not least many thanks to all collaborators of G.O.C. and L.M.C. in Damascus, especially to Mr. Nabil Daher in G.O.C., furthermore to Mr. Khorzom Safwan and to Mr. Awami Jassin in L.M.C. Without their skillful, diligent and well intentioned work, the investigations would not have been carried out in such a short time.

REPORT

The work performed by the UNIDO adviser is summarized as follows:

- the preliminary information, discussion and time table of the adviser activity are reviewed in Annex 1
- the programme of the investigations is outlined in Annex 2.
- the investigations of volcanic materials for making light weight aggregate concretes can be found in Annex 3.
- The most important information about lightweight aggregate concretes are summarized in Annex 4
- the investigations of the pozzolanic activity are shown in Annex 5.

ANNEX No. I

WORK SCHEDULE OF "UNIDO" EXPERT ON THE JOB OF POZZOLANIC MATERIALS.

POST KEY CODE: DP/SYR/80/001/011-03/32.1 K

1.- INTRODUCTION

Abundant raw materials for various building materials industries exist in many parts of the Syrian Arab Republic. Except for the existing cement works, the other building materials industries are not adequately developed so far. There is an intention to introduce some of the most important building materials industries throught the Five Year National Development Plans with wide dispersal of these industries over the widest possible areas all over the country.

It was therefore decided by the Government to request UNIDO/UNDP technical assistance to establish comprehensive studies within the scope of a building materials project as a preliminary stage. Results of these studies were lead to the formulation of a Project Document.

One of the outputs of the project was the development of using pozzolanic materials.

According to the job description, the expert on the field of pozzolanic materials is expected to prepare a feasibi study comprising

a) A full survey for volcanic cinders with pozzolanic activity and clearly classified according to their technological characteristics:

b) Assessment of available data for physical and chemical properties for pozzolans, conducting the performance of further physical and chemical investigations and proposal for research work.

c) Proposal of suitable scope of utilization for various types, drawing up of appropriate quarrying procedures, transport facilities, industrial processes and rational application.

d) Evaluation of the binding properties for pozzolanic materials with hydraulic activites and a study of the technical and economical consequences for the production.

2/...

e) Special study devoted to pozzolans as aggregate of light weight concretes.

f) Study of the possibilities for making precast concrete elements with pozzolan aggregate.

g) Practical demonstration of possibilities for the utilization of coloured pozzolans in concrete for plastering facades.

The expert is also expected to prepare a final report setting out the findings of his mission and his recommandations to the Government on further action which might be taken.

2.- POZZOLANS

The composition of pozzolan or pozzolanic material is siliceous and aluminous, and varies widely. A combination of pozzolan and lime was historically the first hydraulic bindes. This was developed by the Romans more than 2000 years ago for various concrete structures. Parts of such structures still stand today. One of their quarries was near the town Pozzuoli, which provided the name pozzolan for this group of latent hydraulic materials. Pozzolans may be natural in origin or artificial.

Naturally occuring pozzolans include volcanic tuffs and pumicetes, trasses, diatomaceous earths, opaline cherts and some shales, these form pozzolans class N according to ASTM C 618-7_.

Many countries have established specifications for chemical and physical properties of pozzolans. The chemical requirements usually call for a minimum 70-75% of the pozzolan to be composed of $SiO_2 + Al_2O_3 + Fe_2O_3$. Unfortunately, the latent hydraulic ability of a pozzolan depends primarily on its reactive, or soluble, silica, alumina and iron oxide contents, these are not identical not even proportional to the total silica, alumina, and iron oxide contents. The siliceous ingredient is in an amorphous state in a good pozzolan. Crystalline siliceous materials, such as quartz, combine with lime very slowly, except under curing at high temperatures.

3/...

Also calcination, that is, heat treatment, or chemical treatments may increase the reactivity of many latent hydraulic materials but not all of them.

There have been several chemical and physical methods recommended for the determination of the amounts of reactive ingredients in pozzolans, that is, for the prediction how a pozzolanic material will behave in a mortar or concrete, but none of them is completely satisfactory yet.

Two methods are specified by ASTM for the estimation of pozzolanic activity:

1) With portland cement by making sand mortar cubes where 35%, by absolute volume, of the cement is replaced by pozzolan and the obtained compressive strengths are compared to the compressive strengths of comparable control cubes made with 100% portland cement.

2) With lime by making Ø 5 x 10 cm (2x4 in) mortar cylinders that contain 1 part hydrated lime, 9 part of standard sand, by weight, and pozzolan equal to twice the weight of lime multiplied by a factor obtained by dividing the specific gravity of the pozzolan by the specific gravity of the lime. After a special curing of 7 days the compressive strength of these sylinders should be at least 5,5 MPa.

According to the MSZ (Hungarian Standard) the pozzolanic activity is investigated with lime by making 4 x 4 x 16 cm prisms that contain 0,52 part hydrated lime, 0,45 part pozzolan, 0,03 part gypsum and 3 part of standard sand. Gypsum (plaster of Paris) is added to accelerate setting.

Latent hydraulic materials can be used to make cementitious materials in the form of blended cements in different ways. They can be also added to the concrete or mortar mixer together with portland cement and aggregate as finely divided mineral admixtures.

The justification for using latent hydraulic materials can be economical and/or technical.

4/...

It may provide the possibility of reducing cost by saving in the amount of cement used; a concrete containing such a material, if properly and economically proportioned, will usually include a smaller amount of portland cement than would otherwise be required. Therefore these materials may be used as "replacements" or " substitutes" (in German: Ersatz) for part of the portland cement, Since the gravity of most of pozzolans is about 2,5 g/cm^3 and that of the portland cement is about 3,15 g/cm^3, the absolute volume of a replacement by weight will be 20-25% greater than that of the cement which is replaced.

The technical advantages of using latent hydraulic materials are usually more important than the economic reasons. They may serve in the fresh concrete as correctives for mixtures deficient in fine materials. If such a deficiency exists, which is typical for lean concretes, then the proper use of a mineral admixture improves the workability, and reduces the tendency for segregation and bleeding. If, however, the concrete does contain an adequate amount of fines, which is typical for rich concretes, then the addition of a mineral admixture, as a rule, increases the water requirement, or impairs the workability.

Strengths of a concrete with pozzolanic materials are typically lower at early ages, and higher at later ages, than are obtained with portland cement alone. Simultaneously, the temperature rise is decreased, resulting from heat of hydration of the cement. The setting times are also increased by the addition of pozzolanic materials, although the values are usually still within the normal specification limits.

Use of pozzolanic material with other than sulfate - resisting portland cements generally increases resistance of the concrete to agressive attack of sea water, sulfate solutions and natural acide waters. Improved impermeability of the concrete frequently accompanies the use of pozzolan, especially in lean mixtures. In general, the creep of concrete as well as the drying shrinkage are greater when pozzolans are used than when they are not.

5/...

Considering all these, the chief use of latent hydraulic materials is in mass concrete, harbor works, sewers, in hot climat, and when chemical reasons justify it.

3.- LIGHTWEIGHT AGGREGATES

The primary factor controlling the unit weight of a concrete is the average specific gravity of its aggregate. This is the reason that lightweight aggregates are important.

There are two main advantages of lightweight concretes: Lower unit weight and lower thermal conductivity. Structural lightweight aggregate concretes usually have a compressive strength in excess of 15MPa and an air-dry unit weight not exceeding 1900 kg/m^3 at the age of 28 days. Insulating concrete have much lower unit weights not exceeding 800 kg/m^3, with strengths between 0,1-5 MPa. Between these two types can be found the load-bearing and insulating lightweight concrete.

The only way to reduce the bulk specific gravity of an aggregate is by the inclusion of air into the particles. Sometimes this is done by the action of nature, resulting in natural lightweight aggregates, such as pumice. A magnificent example for the application of this kind of lightweight aggregate is the 43m diameter dome of the Pantheon in Rome (Italy) built in the second centry AD.

Most of natural lightweight aggregates - pumices, tuffs, volcanic cinder etc., is strong enough to produce a good lightweight concrete for structural purposes, such as reinforced roof and floor slabs, highway pavements, walls and panels, primarily in the precast industry.

To determine suitability of a lightweight aggregate for concreting, not only properties of aggregate, but its behaviour in concrete mixtures must be investigated. It is well advised to make mixtures of different mixing ratio and to make specimens of different compaction. Having tested the specimens, the relationship between unit weights and compressive strength as well as composition and compacting method of the lightweight aggregate concrete can be proved, which is the basis of effective making concretes of good quality.

6/...

4.- <u>PRELIMINARY INFORMATIONS</u>

The General Organization for Cement (S.A.R.) has made available for expert the following reports:

1) Terminal Report on Assistance to Development of Building Materials.
SI/SYR/76/801, by Mr. A. BOZANOVIC, 20 Oct. 1978.

2) Technical Report on Production of Gypsum Prefabricated Components. Feasibility Study for Gypsum Project.
TS/SYR/76/002, by Mr. Y.A. HUSSEIN, May 1978.

3) Technical Report on Calcium Silicate Bricks Industry
TS/SYR/76/002, by Mr. Y.A. HUSSEIN, June 1978

4) Report on Establishment of Lime Industry in Syria (Hama and Adra).
DP/SYR/80/011-01/32.1K, by Mr. M.V. OREL, April 1981.

5) Report on the Possibility of Use New Building Material in S.A.R.
DP/SYR/80/001/11-01/32.1 K by Mr. M.V. OREL, May 1981

6) Technical Report: Feasibility study for the Industrialization of Concrete Products.
DO/SYR/80/001/11-02/32.1K, by Mr. J.G.KEPINSKI, June 1981.

The most important results and recommandations of these reports are as follows:

The Syrian Arab Republic has considerable potential for the balanced development of rural areas owing to the even distribution of natural resources in one form or another throughout the country. Rural development would be designed to discourage the exodus of labour from the land to the urban centers and to keep skilled workers in rural areas so that both industrial and agricultural development can benefit from their presence.

According to Report of Mr. Bozanovic (1) there are two regions known to have volcanic cinder near to Damascus:

Shahba region and Adra region. In this report some test results can be found. The main reason for investigation of volcanic materials from the Adra region was to determine whether these materials have the necessary characteristics for use as pozzolanic materials and lightweight aggregate.

Unfortunately, this region has no water and it is appr. 25 Kms far from Adra without any road, therefore this territory is not suitable to open a quarry. The result of investigations are presented only for information.

The pozzolanic activity was investigated by making specimens from lime, sand, ground pozzolan and water, but the report does not contain mixing ratios and curing method. The compressive and bending strengths after 7 days were as follows:

	Sample 1	Sample 2	Sample 3
Compressive strength in MPa	10.3	3.6	6.9
Bending strength in MPa	3.3	1.9	2.1

Lightweight concrete specimens were also made for testing the pozzolans were taken out from deposits of Adra region. The results of these investigations can be found in Fig. 1.

Report of Mr. Kepinski (6) deals with the industrialization of concrete products in the Syrian Arab Republic. This report outlines the methods and levels of construction. It states that concreting in site reached high level and good quality, but in Syria any greater, state plant of prefabricating concrete does not until now exist. Little work shops with seasonal work produce some of kind of prefabricated concrete units, they are, however, expensive, therefore the building market is not too much interested in development of prefabrication.

For the Syrian Arab Republic, both from economical and technical reasons, development of prefabrication of concrete is important.

Mr. Kepinski suggests in his report, among others, to develop prefabrication of lightweight aggregate concrete for making masonry units (hollow blocks), floor hollow blocks, wall elements (load bearing and partition walls), first in Adra region, after in Bera, Sweda and Regga regions, because of availability of volcanic materials in these territories.

The other four reports have no data about the volcanic materials and their utilization.

Having studied these reports, the expert discussed his findings with Mr. H.H. Nabulsi. At this fruitful discussion, it turned out that,

a) There are more regions in Syria having volcanic cinders and tuffs: Shahba, Adra, Regga and Haskeri regions. Shahba and Adra are near to Damascus, the others are situated in north part of the country. The results of the investigations carried out until now have promised the possibility of their utilization, they are, however, not sufficient. Therefore the Syrian Government gives priority to further research work for testing volcanic materials derived from different regions;

b) The Syrian Arab Republic is keenly interested in development of prefabricated concrete for the purposes suggested by Mr. Kepinski. Therefore the Syrian counterpart gives priority to the lightweight aggregate concretes in the further research work and pilot plant tests

c) The Syrian Arab Republic is also interested in making hydraulic lime with pozzolanic materials, but the results got until now are not considered satisfactory. Therefore the Syrian counterpart suggests to enlarge the investigations on this field;

d) The Syrian Arab Republic is presently not interested in production of blended cement with pozzolanic materials. Therefore preparing feasibility study for this purpose is not necessary.

9/...

The expert prepared his program taking into consideration the above.

5.- PROGRAMME OF THE EXPERT ACTIVITY

On the basis of above data and preliminary discussion with Mr. H.H. Nabulsi from General Organization for Cement, the following activities of expert are necessary.

a) For producing lightweight aggregate concrete, the available data are very promising but not sufficient. Because of this fact, further investigations should be carried out with samples taken from different deposits. The main goal of the research work is to determine the features of the volcanic materials and methods of technology for making lightweight concretes.

On the basis of litterature and the earlier research work of the expert, relationshop among mixing ratios, concrete compositions, compacting methods, unit weights and compressive strengths of concretes should be determined according to Fig. 2.

In order to reach this goal, investigations should be carried out in laboratory as follows:

- determining characteristics of the raw materials (bulk-density, chemical composition, grading, water absorption in 0.. and .. hours, specific gravity, strength)
- determining characteristics of the fresh concrete mixtures (compactibility, plasticity, segregation)
- determining characteristics of the concrete technology (mixing time, drying of mixture, compaction)
- determining characterisitcs of hardened concrete (unit weight, compressive strength, thermal conductivity).

Lightweight aggregate concrete mixtures should be made with different mixing ratios and compacting methods.
Example of these investigations:

- Mixing ratios by weight:

cement	1	1	1	1	1	1	1	1	1
volcanic material	8	6	5	4	3.3	2.7	5	5	5
natural sand	-	-	-	-	-	-	0.5	1.0	1.5
water	1.4	1.1	0.95	0.8	0.66	0.64	1.0	1.05	1.1

- from these above mixtures of different mixing ratios 9-9 specimens should be made; 3-3 specimens without any compaction, 3-3 specimens compacted slightly, 3-3 specimens compacted storngly, curing: in the first seven days in wet climate, after in laboratory room. Testing compressive strength in 28 days.

During th expert activity only a few samples can be investigated. The other samples will be tested by the Syrian counterpart, utilizing the experiences of the training.

B) For producing hydraulic lime with pozzolans, the available data are promising but not sufficient, because of this fact, further investigations should be carried out with samples taken from different deposits. This research work will be lead by the expert and it also serves for training purposes. The main goal of these investigations is to determine the pozzolanic activity of different volcanic materials.

The research work should be based on the ASTM standards, but it is advisable to use lime+gypsum instead of lime alone. For the better evaluation, the mixing ratios will be modified.

Example for mixing ratios (part by weight):

Hydrated Lime	Gypsum	Pozzolan	Sand
0.67	0.03	0.30	3
0.57	0.03	0.40	3
0.47	0.03	0.50	3
0.37	0.03	0.60	3
0.27	0.03	0.70	3
0.67	0.03	0.30	5
0.57	0.03	0.40	5
0.47	0.03	0.50	5
0.37	0.03	0.60	5
0.27	0.03	0.70	5

11/...

From these above mixtures 6-6 specimens should be made (Advisable:4x4x16cm prisms) for testing them in 7 and 28 days (compressive and bending strength),
Curing: until 7 days in wet climate, after in laboratory room.
With the best mixtures, rendering mortar will be made for testing of mortar's sticking to different surfaces (e.g to ordinary concrete, to lightweight concrete).

Having had test results, the suitable utilization of pozzolans in hydraulic lime can be determined.

During the expert activity, only a few samples can be investigated. The other samples will be tested by the Syrian counterpart, utilizing the experiences of training.

C - On the basis of lightweight aggregate concrete investigations, concrete units should be made for wall construction.

In general, the concrete wall constructions can be made with elements of different sizes:
- masonry-units (generally with hollows, see Fig. 3)
- wall blocks of medium size (Fig. 4)
- wall blocks of large size (Fig. 4)
- panels (Fig. 5)

In the Syrian Arab Republic the elements according to Figures 3 and 4 are suitable.
For making demonstrative wall construction, at least four wall-blocks will be moulded. From these blocks, a wall section can be built according to Fig. 6.

The surface of this wall construction can be used for making rendering mortar of hydraulic lime.

During production, the position of masonry units and wall blocks is vertical in the latter case, the concrete is cast in steel mould supplied with outer vibrators, after vibration the frame will be unclamped and immediately lifted up from the concrete. For demonstrative purposes the blocks will be cast in horizontal position, because in this way the completion of the frame is easier.

D - On the basis of investigations' results, the expert will prepare Technical Report for using pozzolans as hydraulic lime and for using volcanic materials as lightweight aggregates.

6.- TIME TABLE OF EXPERT'S ACTIVITY

Time schedule of the expert's activity can be seen on page 13

7.- APPROVAL

After studying this work schedule and discussing it with the expert, the General Organization for Cement in the Syrian Arab Republic as the Government Implementing Agency of the Project, approves the programme without any modification since it satisfies the demands of the Syrian counterpart The General Organization for Cement gives any assistance necessary to the expert activity.

13/...

Damascus 18th August 1984

Month	Dates	Activity
August	2-5	Briefing in Vienna, arrival in Damascus
August	6-13	Preliminary informations, studying Reports on the field of building materials made by UNIDO experts
August	15-18	Preparing programme of the expert, after its discussing programme's approval by G.O.C.

Month	Dates	Preparing detailed programme of research work and tests	Testing raw materials	Making and testing light-weight aggregate concrete	Making and testing hydraulic lime	Making wall blocks of lightweight aggregate concrete with rendering of hydraulic lime mortars for demonstration purposes	Preparing technical report
August	19-20	↕					
August	22-27	↕	↕				
August/September	29-3		↕	↕			
September	5-10		↕	↕	↕		↕
September	12-17			↕	↕		↕
September	19-24			↕	↕		↕
September/October	26-1			↕	↕	↕	↕
October	3-9			↕	↕	↕	↕
October	10-15			↕	↕	↕	↕
October	17-22					↕	↕
October	24-25						↕

Month	Dates	Activity
October	26-31	Departure from Damascus, debriefing in Vienna

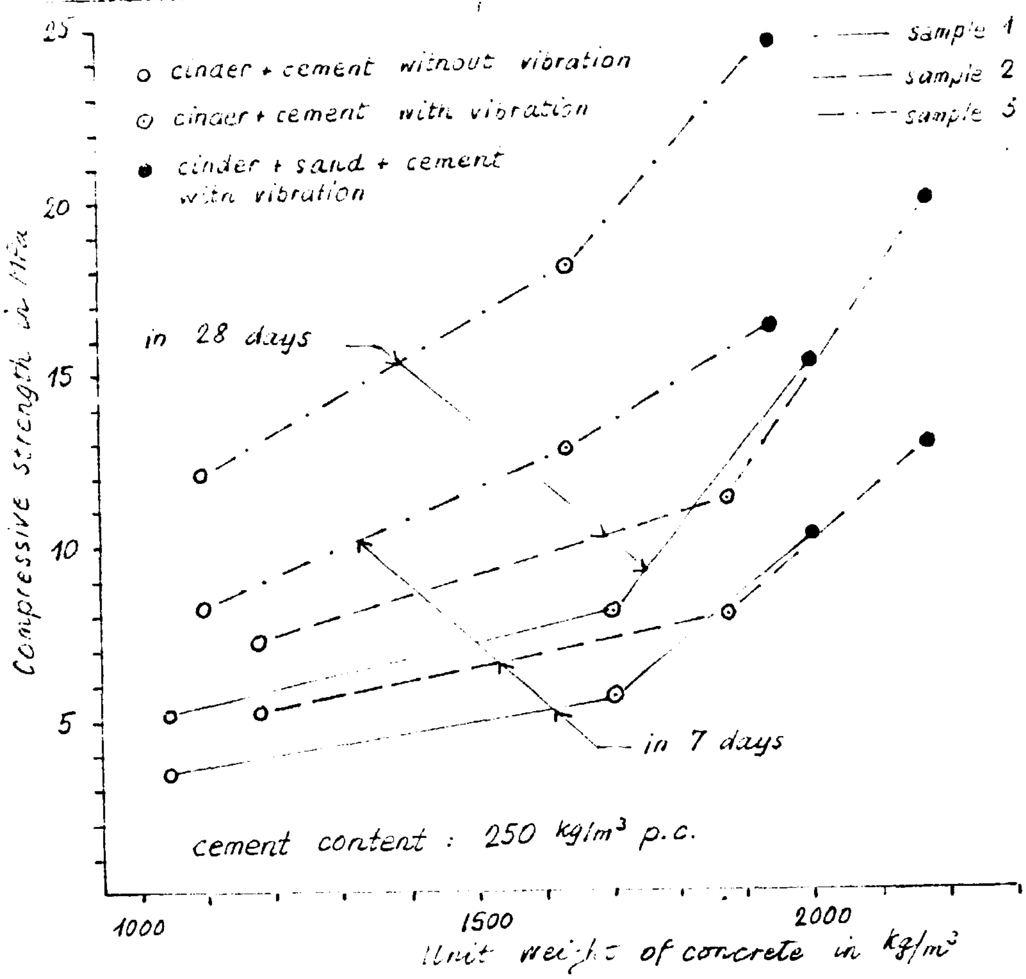


Figure 1.

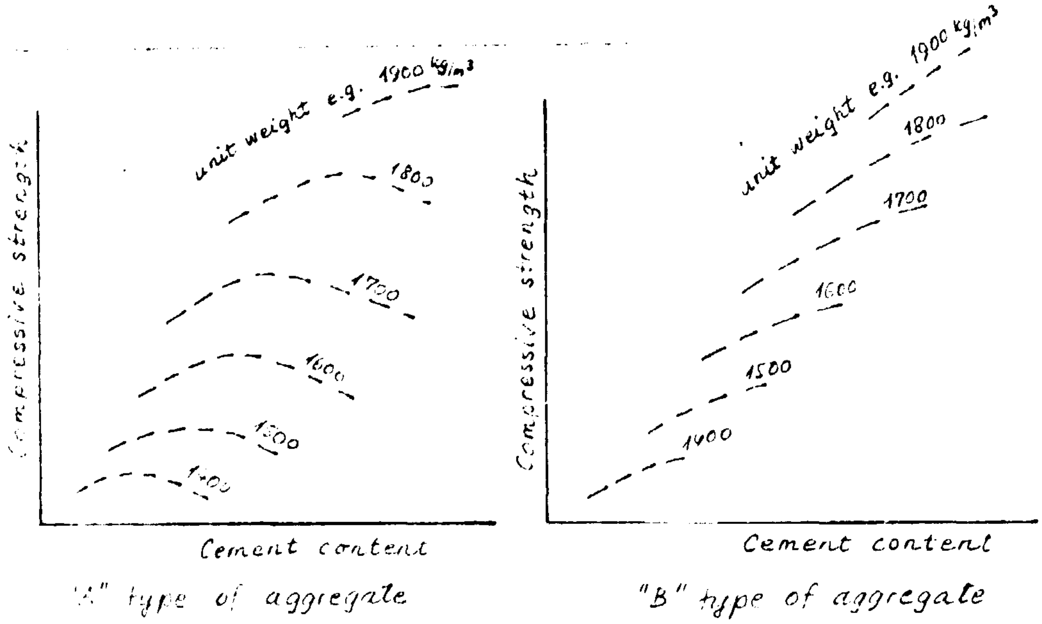


Figure 2.

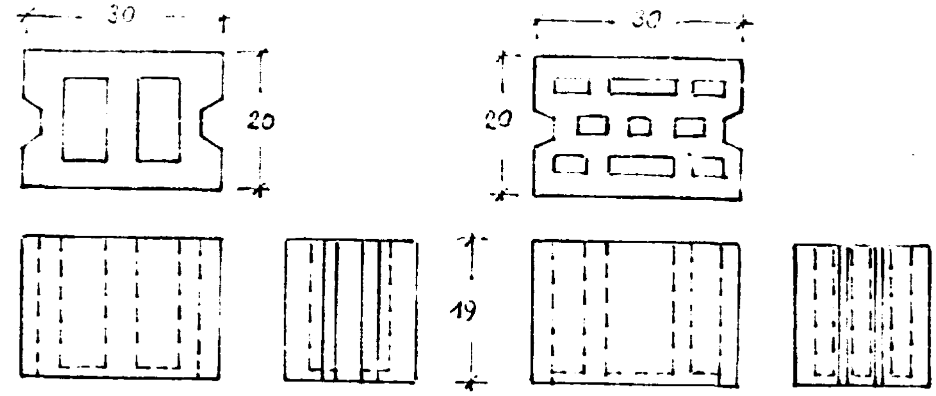
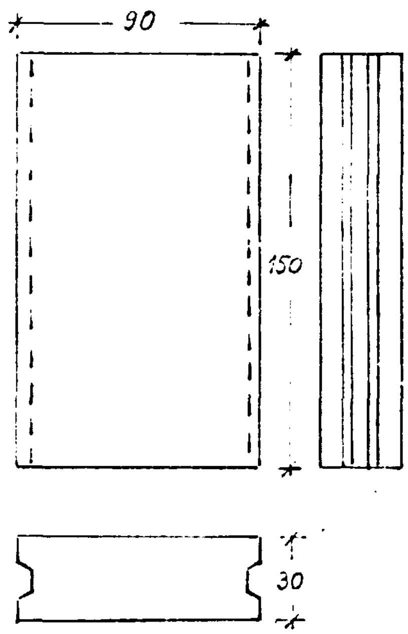


Figure 3. Examples for masonry units



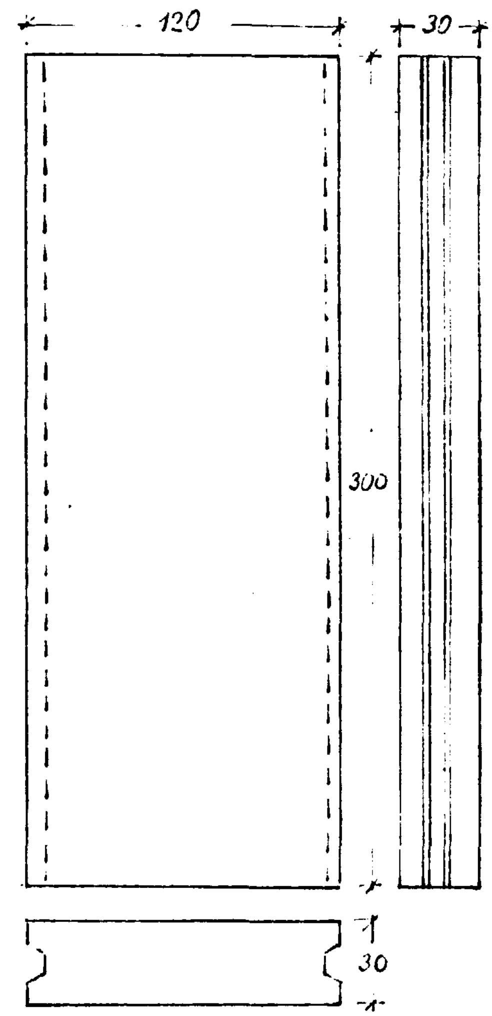
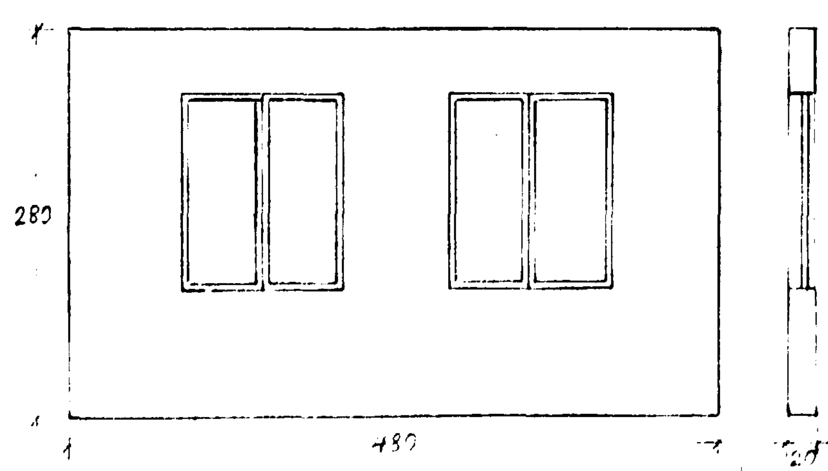


Figure 4. Examples for wall blocks

Figure 5. Example for wall-panel



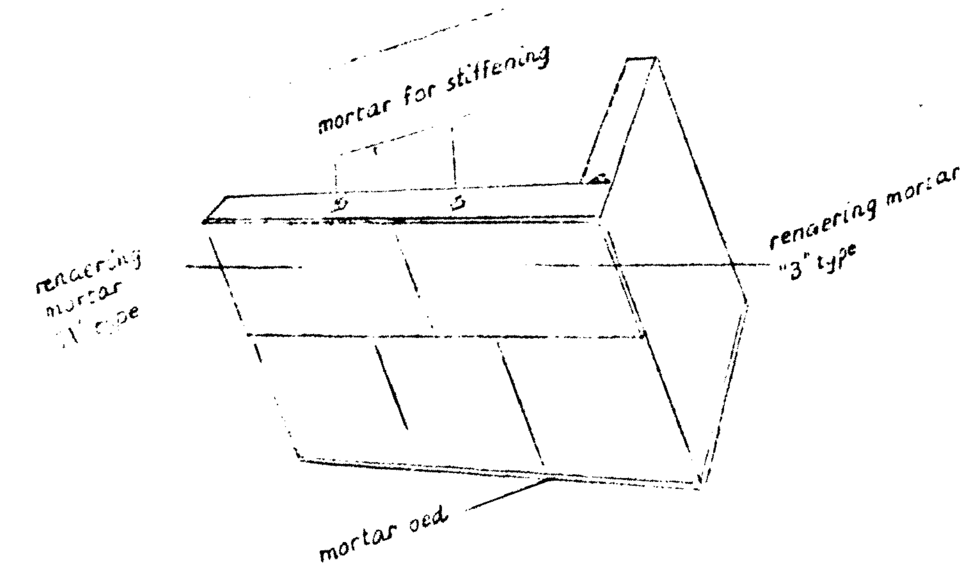

mortar for stiffening
rendering
mortar
type
rendering mortar
"B" type
mortar bed

Figure 6.

A N N E X No. 2

PLAN OF LIGHTWEIGHT AGGREGATE CONCRETE INVESTIGATIONS

1.- INTRODUCTION

The lightweight aggregate concretes - according to the RILEM specifications (RILEM-Réunion Internationale des Laboratoires sur les Essais des Matériaux et des Constructions) - can be divided into three groups.

G R O U P S	Air-dry unit weight in Kg/m2	Compressive strength in MPa	Thermal conductivity in W/mK
Thermal insulating concrete (IC)	≤800	≥ 0.1	≤ 0.30
Load-bearing and thermal insulating concrete (LIC)	≤1600	5-15	≤0.80
Load bearing concrete (LC)	≤1900	> 15	--

Note: According to the ISO Standard: 1 MPa ≈ 10 Kp/cm^2
1 W/mK = 1.163 Kcal/mh°C

The characteristics of the lightweight aggregate concrete depend both on that of the aggregate and on the concrete technology. Therefore making lightweight aggregate concretes of good quality demands the knowledge of aggregate properties and of suitable concreting methods.

2.- PROPERTIES OF LIGHTWEIGHT AGGREGATES

The most important properties of lightweight aggregates are: specific gravity, unit weight, bulk density, grading, strength and water absorption. One part of these properties influence the unit weight and compressive strength of hardened concrete, the other part influence the concrete technology.

Bulk density and strength of lightweight aggregates depends on each other, for different aggregates this relationship is, however, not the same according to Fig. 1.

For testing bulk-density (SAB), pot of 1 dm^3 in Vol. and oven dry aggregate have to be used. Bulk density can be tested for loose and for slightly compacted (shaken) aggregate:

$$SAB = \frac{m_{TA} - m_P}{V_P}$$

where: m_{TA} = weight of pot full with aggregate, g
M_P = weight of pot, g
V_P = volume of pot, cm^3

The characteristical bulk density of aggregate is that of the aggregate of 4-16 (or 4-12) mm in grain size.

Note: According to ISO Standard, the grain size (sieve mesh) has to be interpreted on sieves quadratic aperture.

Having had specific gravity, unit weight and bulk density of lightweight aggregate, pore content of aggregate can be calculated:

Pore content of grains: $P_G = \frac{SA - SAU}{SA} 100$ % in Vol.

Pore content of aggregate heap (with given grading):

$$P_A = \frac{SA - SAB}{SA} 100 \text{ \% in Vol.}$$

Pore content among grains

$$P_{AB} = P_A - P_G \quad \text{\% in Vol.}$$

For interpretation of pores in lightweight aggregates is shown in Fig. 2

The different properties of aggregate can be investigated as follows:

Specific Gravity (SA) can be investigated by common chemical methods: $SA = \frac{M_A}{V_S}$

where: M_A = weight of oven dry aggregate in g
V_S = solid volume of aggregate in cm^3

For investigating Unit Weight (SAU) coarser grains are needed. If the grains have more big holes on their surfaces, paraffin coating has to be used. If the grain surfaces are plain, measuring with water saturation is advisable:

$$SAU = \frac{M_{AG}}{V_G}$$

where: M_{AG} = weight of oven-dry grains in g
V_G volume of grains (together with inner pores) in cm^3

<u>Grading</u> should be measured by sieving. The ISO Standard prescribes sieves of 0.063, 0.125, 0.25, 0.5, 1, 2, 4, 8, 16, 32 etc mm in mesh.

<u>Aggregate Strength</u> can be investigated by different methods. The Hummel-method determines the crumbling factor of grains (in German : Zertrümmerungsgrad). Testing: from grains of 4-12 mm in size, 0.5 dm^3 will be measured (having known bulk density, it can be weighed) and poured into cylinder (steel mould) of 15 cm in diameter and laid out uniformly on the bottom. The grain will be pressed by steel piston of 14.8 cm in diameter during 1.5 min with 5 Mp.
Before and after pressing, the aggregate grading has to be investigated on sieves of 1, 2, 4, 8 and 12 mm in mesh.
The crumbling factor can be determined according to Fig. 3

<u>The Crumbling Factor</u> :

$$C = \frac{(100+100+100+50)}{100} - \frac{a_1+a_2+a_3+a_4}{100}$$

i.e. the crumbling factor corresponds with the difference of fineness moduli of the original and crumbled aggregates measured on sieves of 1,2,4,8 and 16mm in mesh.

ASTM method uses cylinder of 3 inches in diameter and of 5 inches in height (Ø 76.2 x 127 mm). The aggregate will be poured during shaking into the cylinder, smoothed by steel ruler and pressed until its upper surface becomes dented up to 25 mm (1 in). The diameter of steel piston for pressing is 76 mm.

When the aggregate surface becomes dented to 25 mm, the pressing force (P) is read and the strength of aggregate:

$$R_A = \frac{P}{F} \quad \text{in MPa}$$

where: P = pressing force in N (1 Newton ≈ 10 kp)
F = aggregate surface in mm^2 (since the piston diameter is 76mm, the surface is F = 4536 mm^2)

The figure 1 shows data for aggregate strengths investigated by ASTM Method.

Water Absorption must be measured on air-dry aggregate of given grading in 0.5 hour and in 1 hour by Saturating gradually. The water absorption:

$$A_W = \frac{M_{AW} + M_A}{M_A} \; 100 \quad \% \text{ in weight}$$

where: M_A = weight of air dry aggregate in g
M_{AW} = weight of saturated aggregate in g

In general, water to be added to the lightweight aggregate concrete mixture depends on the water absorption after 0.5 hour. In extremely dry climate and long transportation distance between mixer and mould, the water absorption after 1 hour should be taken in account.

CHARACTERISTICS OF MAKING LIGHTWEIGHT AGGREGATE CONCRETES

Target of making is to produce concrete of given (designed) unit weight and of given (designed) strength. As a rule of thumb: the heavier a material is, the higher is its strength. This thumb rule is, however, not always usable for the lightweight aggregate concretes.

The unit weight of concrete depends on weight of ingredients (cement, aggregate, water) and on the effectivness of compaction.

e.g. it is possible to make lightweight aggregate concrete of 1 m^3 in Vol. with 200 kg of cement, 1000 kg of aggregate and 230 kg of water without any compaction. The unit weight of fresh concrete will come to SCF = 200+1000+230= 1430 kg/m^3. When the same concrete mixture is strongly compacted, the quantity of ingredients increases proportionally and the concrete composition becomes as follows: 260 kg of cement, 1300 kg of aggregate and 300 kg of water. The unit weight of fresh concrete: SCF = 260+1300+300=1860 kg/m^3.
If 385 kg/m^3 of cement is used instead of 200 kg/m^3, the unit weight of fresh concrete can be 1640 kg/m^3 without compaction and 2140 kg/m^3 with strong compaction.

Compressive strength of concrete does not always follow its unit weight, same compressive strength can be reached by different unit weights or decreasing strength can connect with increasing unit weight. It depends on mixing ratio and compaction.

For facilitating comprehension, some test results are given in Table 1. In this table can be seen the change of compressive strength and unit weight depending on mixing ratio and compaction. These results are processed in Figure 4&5.

It is to be noted that the unit weight of dried concrete can be also calculated, with good approach, from the concrete composition: cement combines chemically - during its hardening in the first 2-3 months - approximately 20 pct of its weight. Consequently, the unit weight of dried concrete:

$$SCD = M_C + M_A + 0.2\ M_C$$

where: M_C and M_A = cement and aggregate content of concrete in kg/m^3

In upper part of Fig. 4 can be seen the change of unit weight depending on mixing ratios and compacting methods, plotted against the cement content. It is to be noted that the cement is resulted from the others factors: e.g. if the mixing ratio is 1:5:1.15 (cement:aggregate:water by weight) and the unit weight of fresh concrete (without compaction) is 1430 kg/m^3, the quantities of ingredients:

Weight of cement: $M_C = \frac{1430}{1+5+1.15} = 200\ kg/m^3$

Weight of aggregate: $M_A = \frac{1430}{1+5+1.15} = 1000\ kg/m^3$

Weight of water: $M_W = \frac{1430}{1+5+1.15} = 230\ kg/m^3$

Mixing Ratio part By Weight	Compaction	Unit Weight in Kg/m^3 of Fresh Concrete	Unit Weight in Kg/m^3 of Dried Concrete	Concrete Composition of Cement in kg/m3	Aggregate in kg/m3	Water in kg/m3	Compressive Strength in 28 Days in MPa
1:8:1.75	Without	1344	1150	125	1000	219	1.3
	Slightly	1470	1260	138	1094	238	2.2
	Strongly	1747	1487	163	1300	293	7.5
1:6:1.35	Without	1392	1200	167	1000	225	2.1
	Slightly	1520	1310	182	1092	246	3.6
	Strongly	1810	1560	217	1300	293	11.2
1:5:1.15	Without	1430	1240	200	1000	230	3.0
	Slightly	1558	1332	218	1090	250	4.7
	Strongly	1859	1612	260	1300	299	14.6
1:4:0.95	Without	1488	1300	250	1000	238	3.8
	Slightly	1615	1411	271	1036	258	5.8
	Strongly	1934	1690	325	1300	309	20.0
1:3.3:0.81	Without	1548	1364	303	1000	245	4.8
	Slightly	1668	1468	326	1077	265	6.7
	Strongly	2012	1771	394	1300	320	26.3
1:2.6:0.67	Without	1643	1462	385	1000	258	5.6
	Slightly	1770	1577	416	1078	276	7.9
	Strongly	2136	1900	500	1300	335	34.8

TABLE 1

And when the unit weight comes to 1859 kg/m^3 (for concrete compacted strongly:

Weight of cement $M_C = \frac{1859}{7.15} = 260\ Kg/m^3$

Weight of Aggregate $M_A = \frac{1859}{7.15} \cdot 5 = 1300\ Kg/m^3$

Weight of Water $M_W = \frac{1859}{7.15} \cdot 1.15 = 299\ Kg/m^3$

In lower part of Fig. 4 can be seen the change of compression stength - drawing with continuous lines - depending on mixing ratios and compacting methods, plotted against the cement content.

7/...

As it was mentioned, target of making lightweight aggregate concrete is to produce concrete of given unit weight and of given strength. This target can be achieved, if factors governing these two properties are known. The relationship between cement content and unit weight of fresh concrete (Fig. 4, upper part), as well as the relationship between cement content and compressive strength (Fig. 5., lower part) enable to plot the graphs of the relationships among cement content, unit weight of fresh concrete and compressive strength. Method of drawing can be seen on Fig. 4 also without further information.

The relationship among cement content, unit weight of dry concrete and compressive strength can be seen in Fig. 5 plotting its graphs on data of Table 1.

Fig. 5 lends itself particularly well to determine composition and compaction of lightweight aggregate concrete.

e.g. task should be to make concrete of compressive strength of 14MPa and of dry unit weight of 1600 Kg/m^3.
From Fig. 5 (lower part) can be seen that this is possible only in the case if the cement content is between 280-320 kg/m^3 and compacting is effective. When constant unit weight (1600 Kg/m^3) is kept, increasing cement content demands decreasing compaction and it results decreasing compressive strength. If cement content increases and compaction is constantly strong, unit weight of concrete also increases, by this means its thermal conductivity will be worsening.

Relationships according to Figures 4 and 5 should be determined for different cement types and different aggregate gradings. In many cases dosage of natural sand (0-1 mm in size) improves compressive strength of concrete, its unit weight, however, increases.

The water content depends on required plasticity. If water content increases, workability of concrete improves, both unit weight and compressive strength can increase. Water-cement ratio does not govern the characterisitics of lightweight aggregate concrete as in the case of ordinary one.

8/...

The other properties of lightweight concrete (e.g. bending strength, shrinkage, creep, young modulus, adhesion of steel bars etc.) depend on its compressive strength. For the statics calculation, these other properties have to be also investigated.

4.- INVESTIGATIONS OF LIGHTWEIGHT AGGREGATE AND LIGHTWEIGHT AGGREGATE CONCRETE

According to the previous informations, the Syrian Arab Republic needs, first and for most, IC and LIC lightweight concretes. Consequently the target of research work is making these concrete types.

4.1- INVESTIGATIONS OF LIGHTWEIGHT AGGREGATES

The investigations require about 30 kg of aggregate from each sample. In each of sampling, a large number of sample increments, that is, small portions, are required to estimate the true average quality of an aggregate with acceptable reliability. Test proportions from the sample may be extracted by quartering according Fig. 5.

Required quantities for testing are as follows:

Testing specific gravity needs	3x0.1kg portions
Testing unit weight needs	3x15 pieces of coarse aggregate
Testing bulk density needs	3x2kgportions
Testing grading needs	3x5Kg portions
Testing [illegible] needs	3x1 dm^3 portions
Testing water absorption needs	3x1 kg portions

Required equipments for testing are as follows:

For specific gravity:	Laboratory mill for grinding Le Chatelier flask (pycnometer) analytical balance kerosene or water, oven for drying at + 105°C

The usual method for determining the true specific gravity aggregate is to powder the sample to, say, 100 mesh (150µm) and then to determine the specific gravity by some method, such as ASTM C 188 for cement (by using inert kerosene or water in a Le Chatelier flask).

The point to the powdering is not so much to destroy void spaces, since most aggregates have pores for smaller than any reasonable sieve opening, but rather to provide particles so small that their pores are readily and completely penetrated by the pycnometer fluid, for instance under vaccum saturation.

For testing unit weight: Pot of 2dm^3 in volume for saturation analytical balance: balance for weighing in water or equipment for measuring displacement; oven for drying at + 105°C

The methods for determination of the unit weight of aggregate are based on weight and volume measurements. Of course, the volume of grains could be determined from dimensional measurements if the sample pieces were regular geometric shapes. Since this is not the case for aggregate particles, the volume has to be measured by weighing in water (in Archimedes-balance) or by displacement. Before this measuring, the particles should be saturated by water or coated with paraffin.

For testing bulk density: Pot of 1 dm^3 in volume balance of gramm accuracy oven for drying at + 105°C

Bulk density of 4-12 mm grains has to be measured loosely. This is the characteristic bulk density of aggregates. For technological purposes, bulk density of given grading of aggregate may be measured after shaking. The measuring pot, full with aggregate, should be hit against a steel plate 15 times, dropping from about 5 cm height. The aggregate surface sank under the influence of shaking should be refilled.

For testing grading: Balance of gramm accuracy sieves according to ISO Standard

The most important particles of lightweight aggregates are the grains below 1 mm. These grains form together with cement the cement mortar (mortar matrix) which is the load bearing skeleton in the concrete.

For testing strength: Balance of gramm accuracy; steel cylinder (Ø 7.62 x 12.7cm according to ASTM Standard or Ø 15cm, according to DIN Standard); steel piston or plate; hydraulic pressing machine with pressing capacity at least 10kN

Testing strength may be carried out according to the ASTM Standar or Hummel-method (DIN Standard). Results are necessary for evaluating the concrete composition as well as the available compressive strength of lightweight aggregate concrete.

For testing water saturation: Pot of 2 dm^3 in volume; balance of gramm accuracy; stopper watch or alarm clock; blotting paper, filtering textile or strainer

Results of testing water absorption may be used for evaluation of mixing water. Air dry aggregate of given grading is poured into the pot which contains water layer of 2cm in height.

After 5 minutes, water surface is increased with 2 cm. After 0.5 hours, the aggregate, together with filtering textile or strainer will be raised from the water, its surface blotted by paper and weighed. This manipulation should not last more than 5 minutes. Having weighed, the aggregate, together with filtering textile or water, will be replaced in water and remained there for once more 0.5 hour. Then the weighing will be repeated.

4.2.-INVESTIGATIONS OF LIGHTWEIGHT AGGREGATE CONCRETES

The investigations require about 300 kg of aggregates from each sample. The target of these testing is to draw the relationships a mong mixing ratios, concrete compositions, compacting methods, unit weights and compressive strengths of concretes according to Figures 4 & 5. The principles of the research work are described in the Work Schedule (Article 5.4).

Required equipments for testing are as follows:

Testing workability: Any equipments used for investigation of ordinary concrete workability (it may give preferance to vibrating systems such as VEBE - meter)

11/...

Testing concrete mixtures: Mixer of 100 dm^3 in volume capacity (for lack of mixer machine, mixing by hand may be carried out)

Moulds for making specimens (cubes, or cylinders or prisms, it is advisable using cylinders of 10cm in diameter and of 20cm in height, but it is possible using cylinders of Ø 15x30cm)

Table vibrator (for lack of vibrator, stamper may be used)

Hydraulic pressing machine

Testing lightweight aggregate concrete should be paid attention

- to the uniformity of concrete workability therefore mixing water should be accordance with the water absorption of aggregate in 0.5 hour + 15 pct of cement content if the cement: aggregate ration > 1:4 (e.g 1:3)
- to the uniformity of aggregate grading therefore the aggregate fractions should be mixed for enabling to get average quality.
- to the uniformity of curing therefore on the first 7 days specifimens should be stored in fog chamber or under wet clothes or in the first day under wet clothes then to 7 days in water.
- to smoothness of pressed surfaces of specifimens, therefore the surface should be leveled by 1:3 cement sand mortar layer on the 7 days before testing compressive strength.

4.3. INVESTIGATIONS OF POZZOLANIC ACTIVITY OF VOLCANIC MATERIALS

The method of investigations is outlined in Work Schedul (Articles 2 and 5.B)

Required quantities of materials (for one type):

- ground volcanic material with specific surface at least of 3000 cm^2/g — 4 kg
- hydrated lime — 4 kg
- gypsum (paris plaster) — 0.5 kg

- Natural sand of 0-3 mm (commonly used in the S.A.R. for mortars) 25 kg

Required equipments to the investigations

- Ball mill for grinding volcanic materials to specific surface at least of 3000 cm^2/g
- mixer with capacity of 10 dm^3 in volume (commonly used to cement quality control)
- moulds for making specimens (it is advisable to use prisms of 4x4x16 cm)
- Shaking table for investigating mortar plasticity and for compacting specimens (commonly used to cement quality control)
- cone for investigating mortar plasticity (commonly used for cement investigations)
- hydraulic pressing machine for testing compressive and bending strengths
- balance of g accuracy

Six specimens will be made from one mixing ratio : three specimens tested in 7 days, three specimens tested in 28 days for compressive and bending strengths. The mixing ratios are given in Work Schedule, Article 5.B.
Mixing time: 0.5 minutes mixing hydrated lime, gypsum and ground volcanic material + 0.5 minute mixing with sand + 1 minute mixing with water.

Plasticity:	The mortar should be stretched to 16-18cm.
Compacting:	Shaking on table 15 times
Curing:	7 days (or 14 days) in fog chamber (or under wet clothes or in water after 1 day) then in laboratory room.

4.4. MAKING LIGHTWEIGHT AGGREGATE CONCRETE UNITS

In accordance with the Work Schedule, for making demonstrative wall construction, at least four wall blocks should be moulded.
It is advisable to make wall blocks of medium size, that is of 150x30 cm in measures. The mould may be formed of boards according to Fig. 6.

The moulds are placed on smooth, hard surface. Surfaces of the bottom plate and sideboards are coated with thin oil layer to prevent them from sticking to the concrete.

The concrete mixture is poured into the form, laid out uniformly that it would top of about 10 cm the board in height. Concrete can be compacted by poking vibrator and for smoothing its surface, plank vibrator may be used.

After one day, the side boards may be carefully removed and the block may be set up by lifting one side of bottom plate by hooks (Fig. 7)

Required quantities of materials:

- volvanic material of 0-16mm in grain size 1800kg
- natural sand of 0-1mm in grain size 500kg
- cement (350 pc) 500kg
- Water (approximately) 400kg

Quantity of lightweight concrete (for four blocks) comes to 1.6 m^3.

Mixing ratio (probably): 1:4:0.9 (cement; aggregate: water) by weight.

Aggregate (probably): 85 pct by W. of lightweight aggregate
15 pct by W. OF NATURAL SAND

Curing: during seven days by continuous watering.

29th August 1981 J.E. UJHELYI

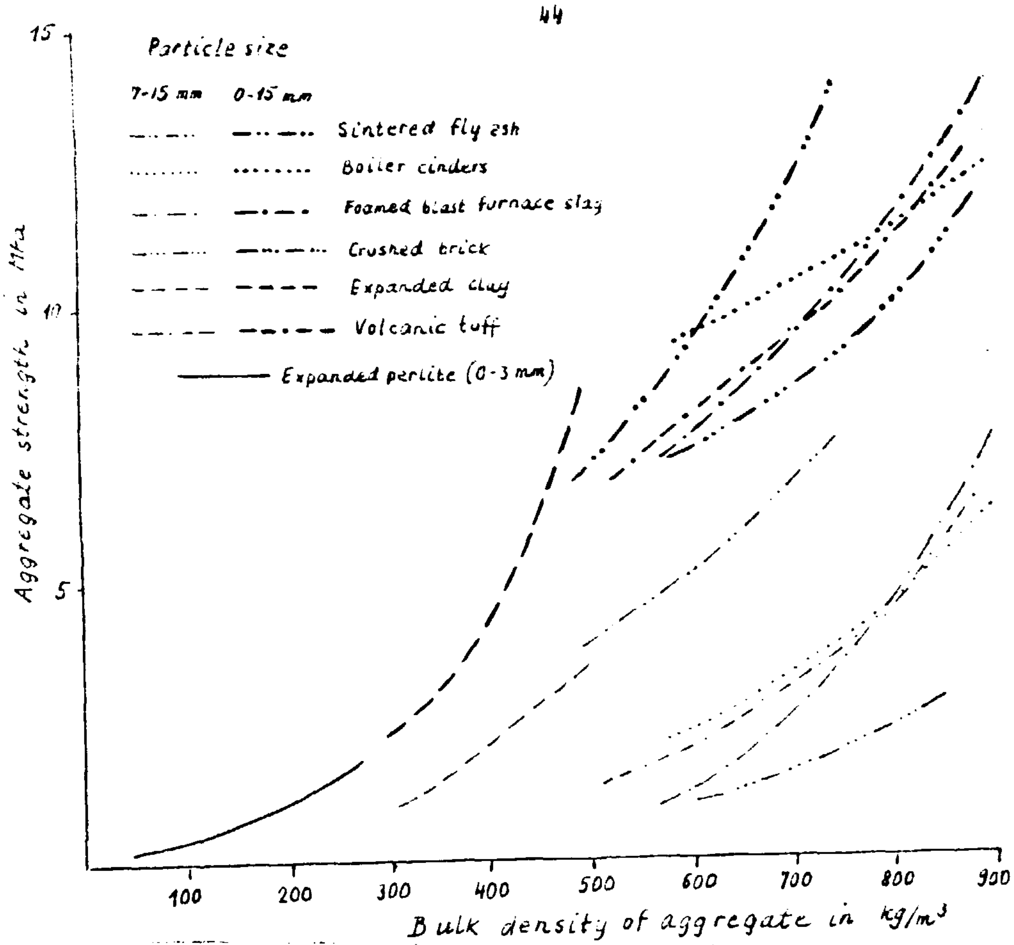


Fig. 1.

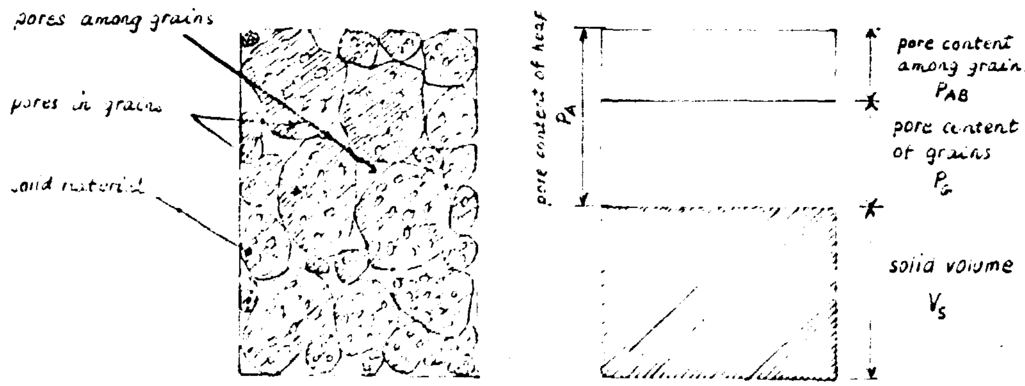


Fig. 2.

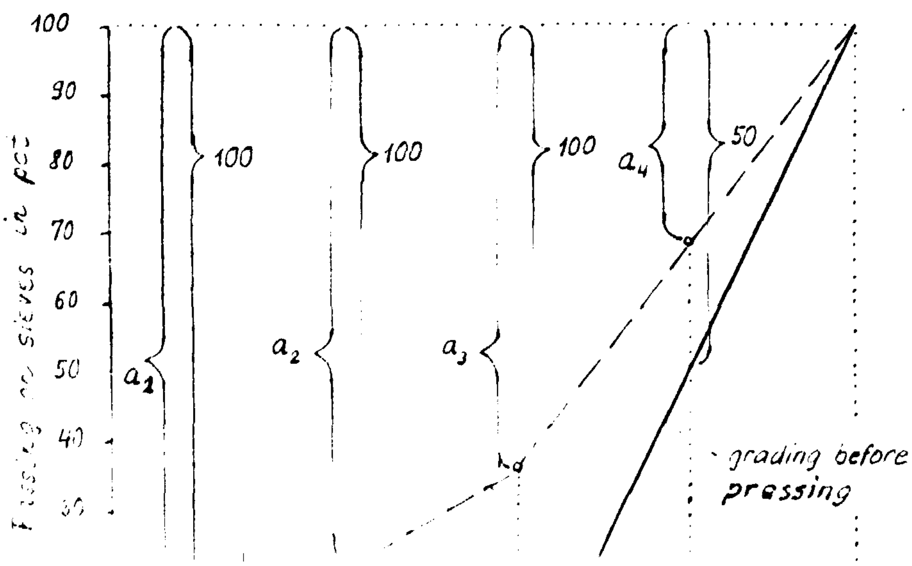


Fig. 3.

SECTION 2

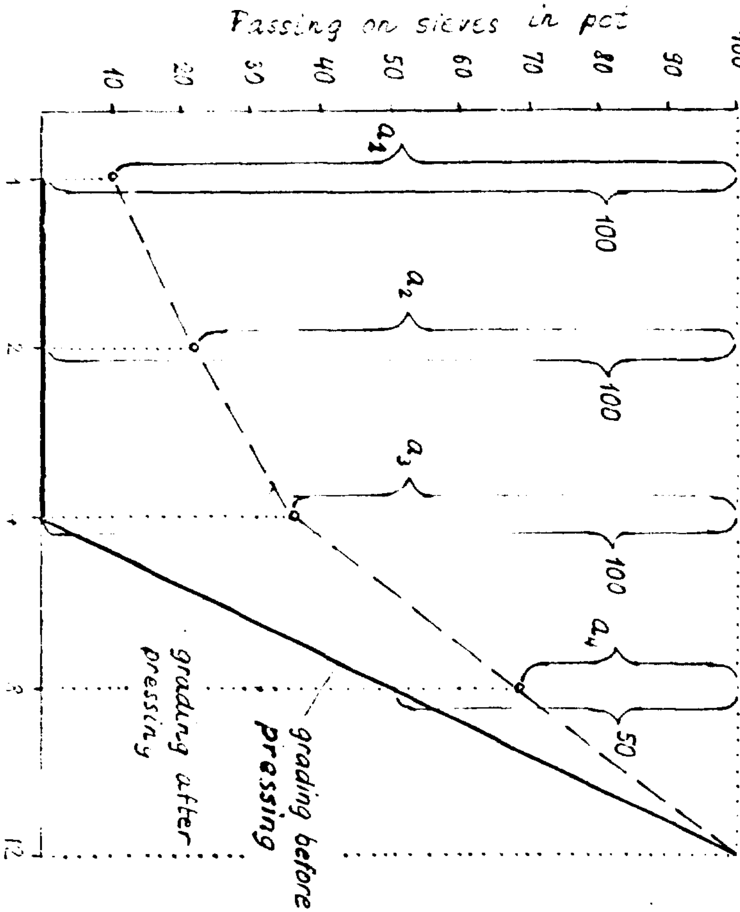


Fig. 3.

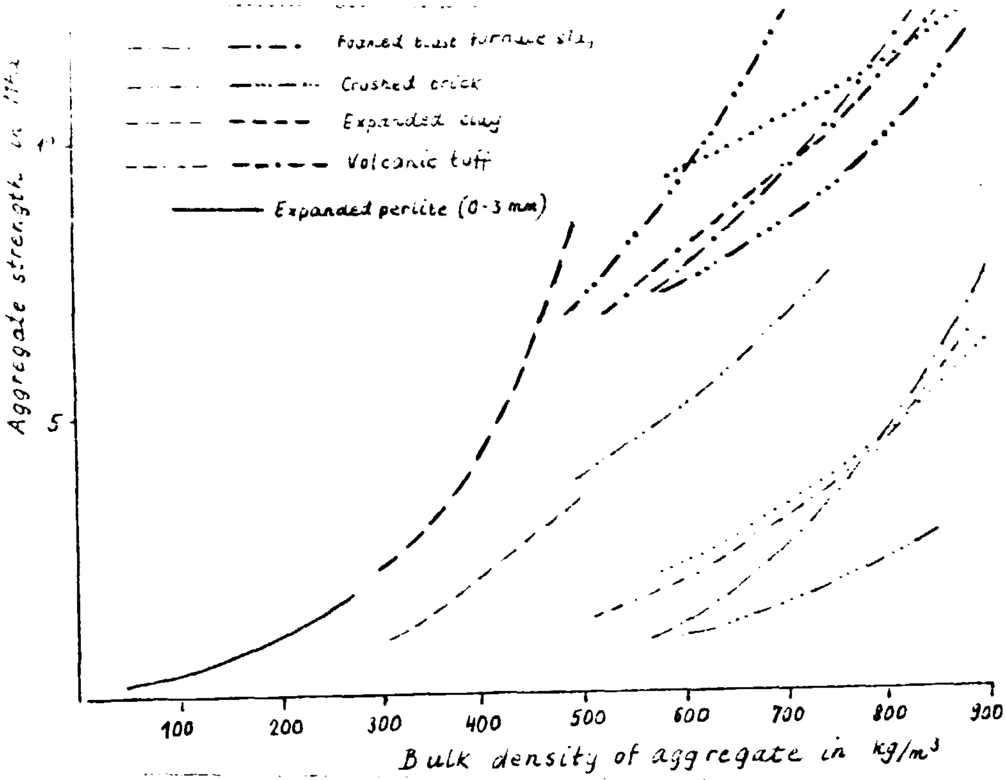

Foamed blast furnace slag
Crushed brick
Expanded clay
Volcanic tuff
Expanded perlite (0-3 mm)
Aggregate strength in MPa
5
100
200
300
400
500
600
700
800
900
Bulk density of aggregate in kg/m³

Fig. 1.

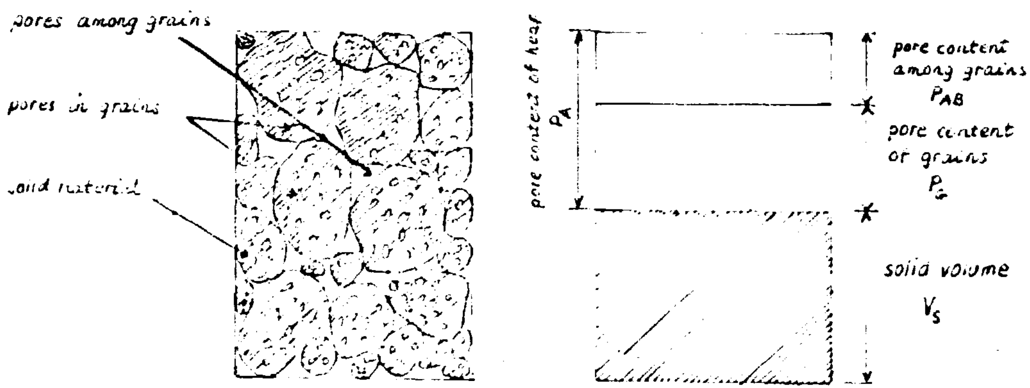
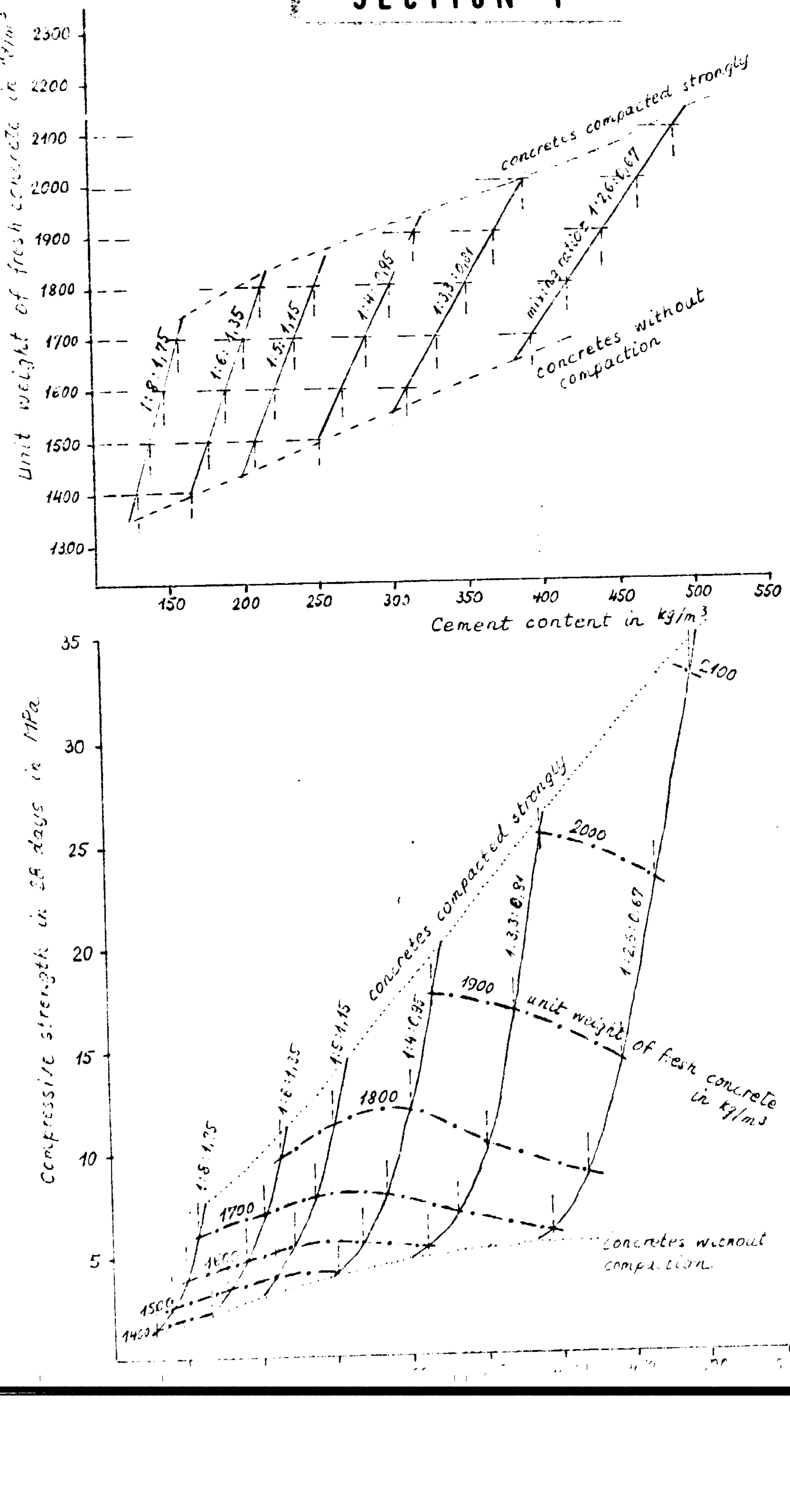
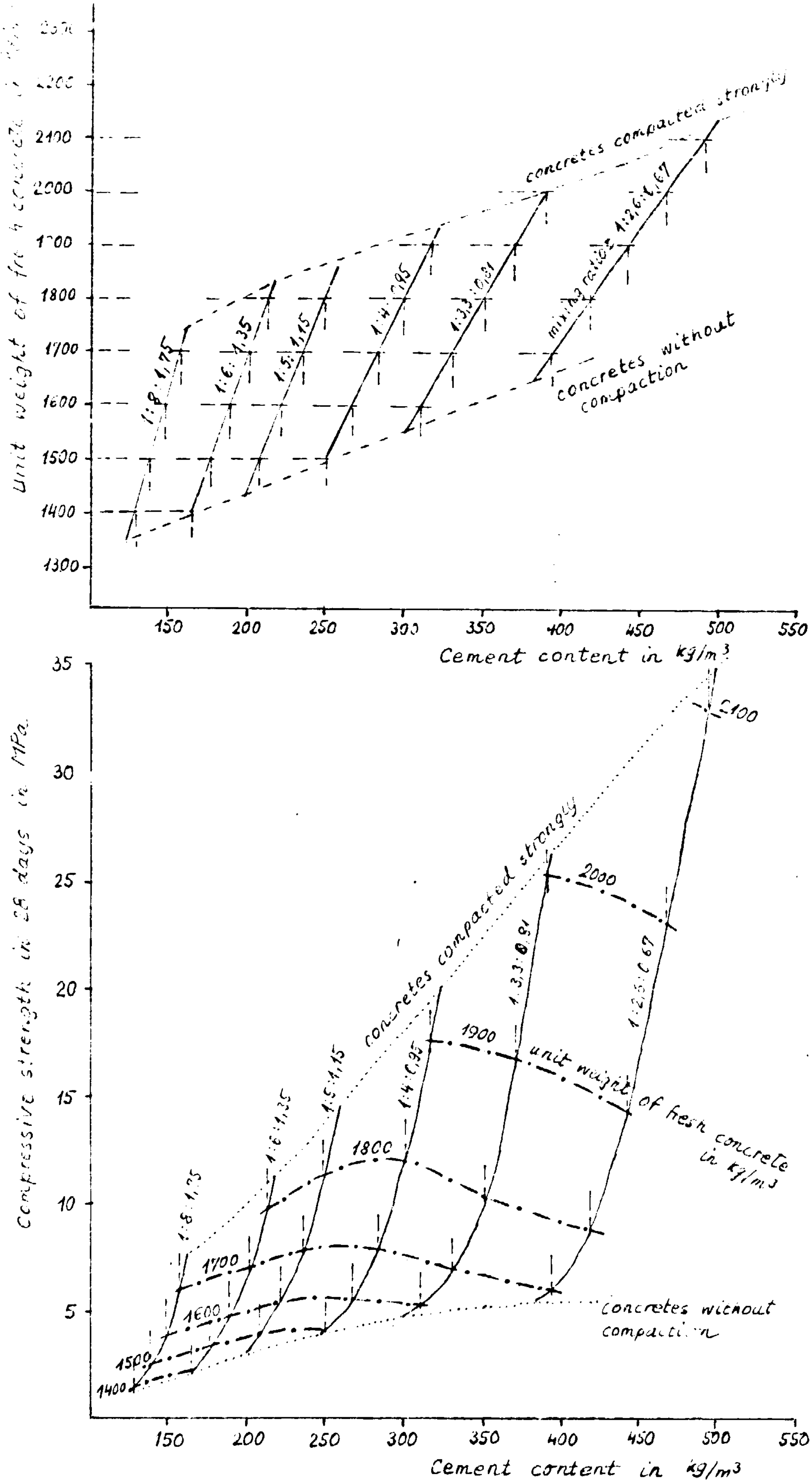

pores among grains
pores in grains
solid material
pore content of heap
P_A
pore content among grains
P_{AB}
pore content of grains
P_G
solid volume
V_S

Fig. 2.

Figure 4.

SECTION 1

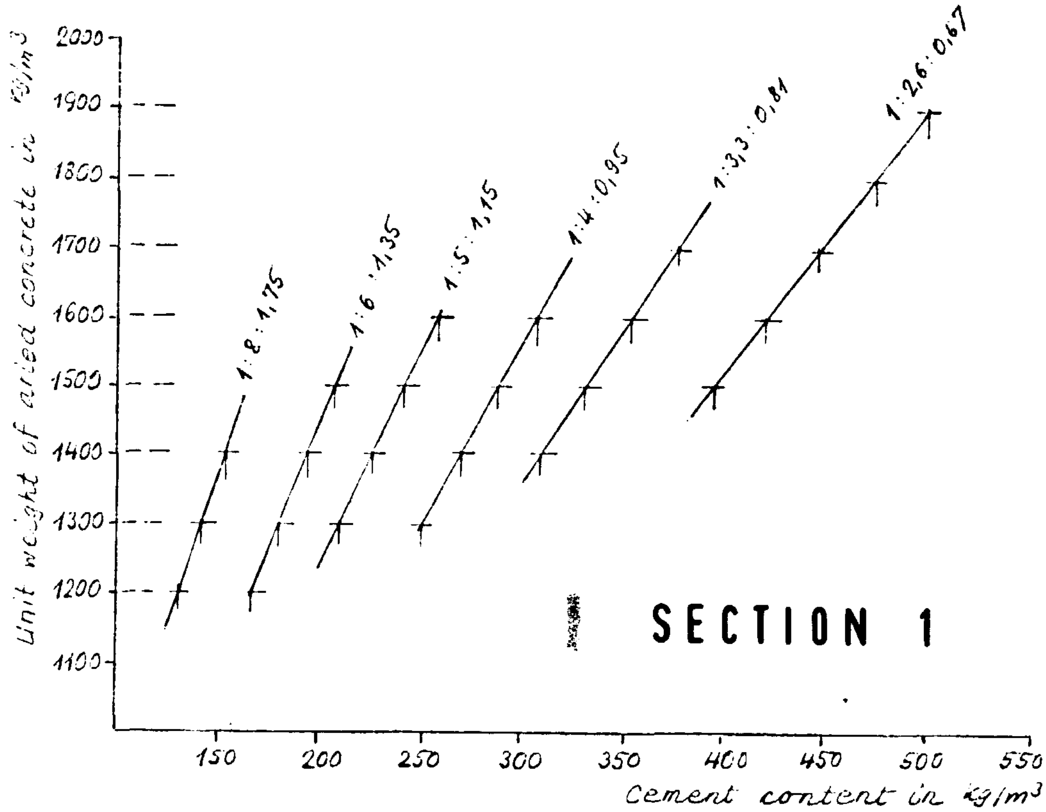


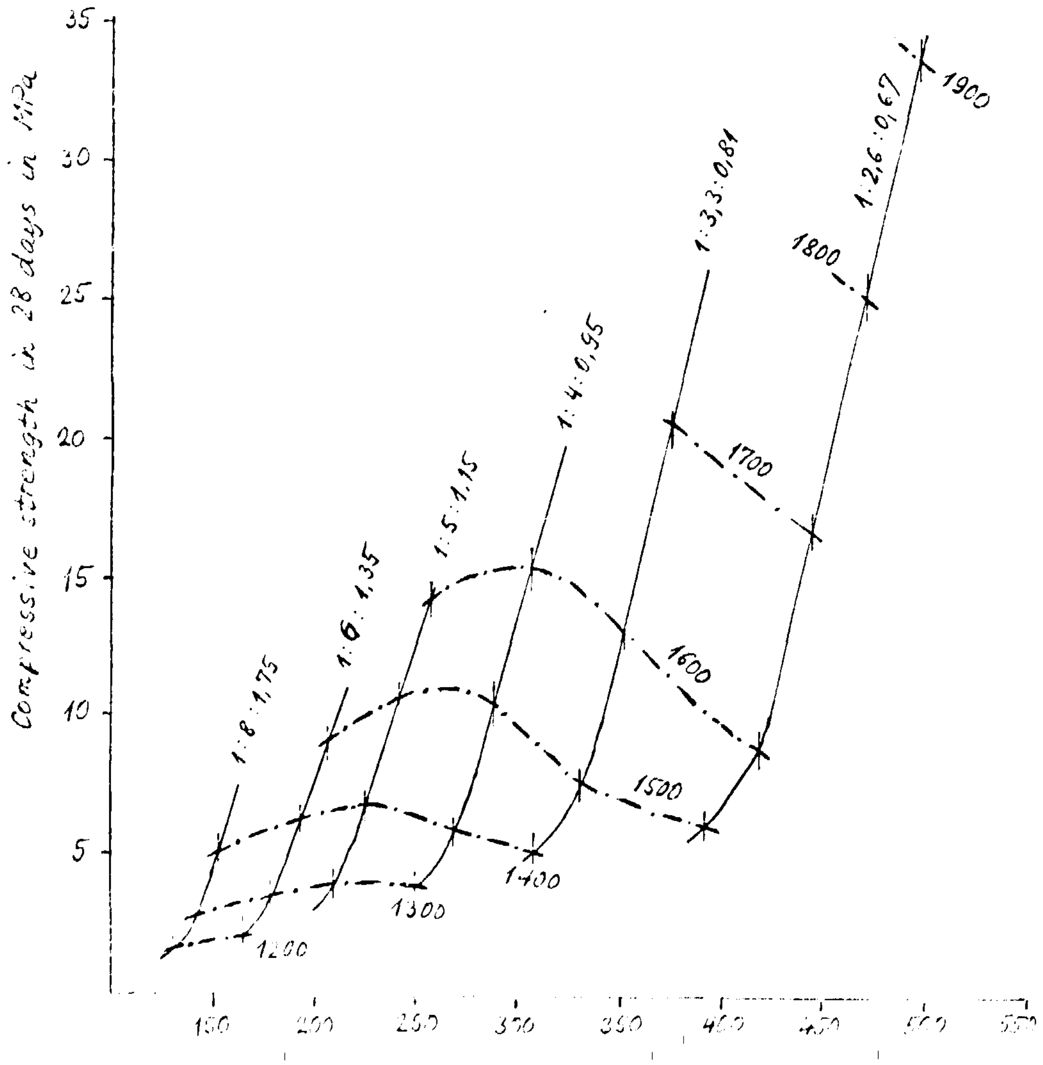


Relationship among cement content, mixing ratio, compacting method, compressive strength and unit weight of fresh light
[illegible]

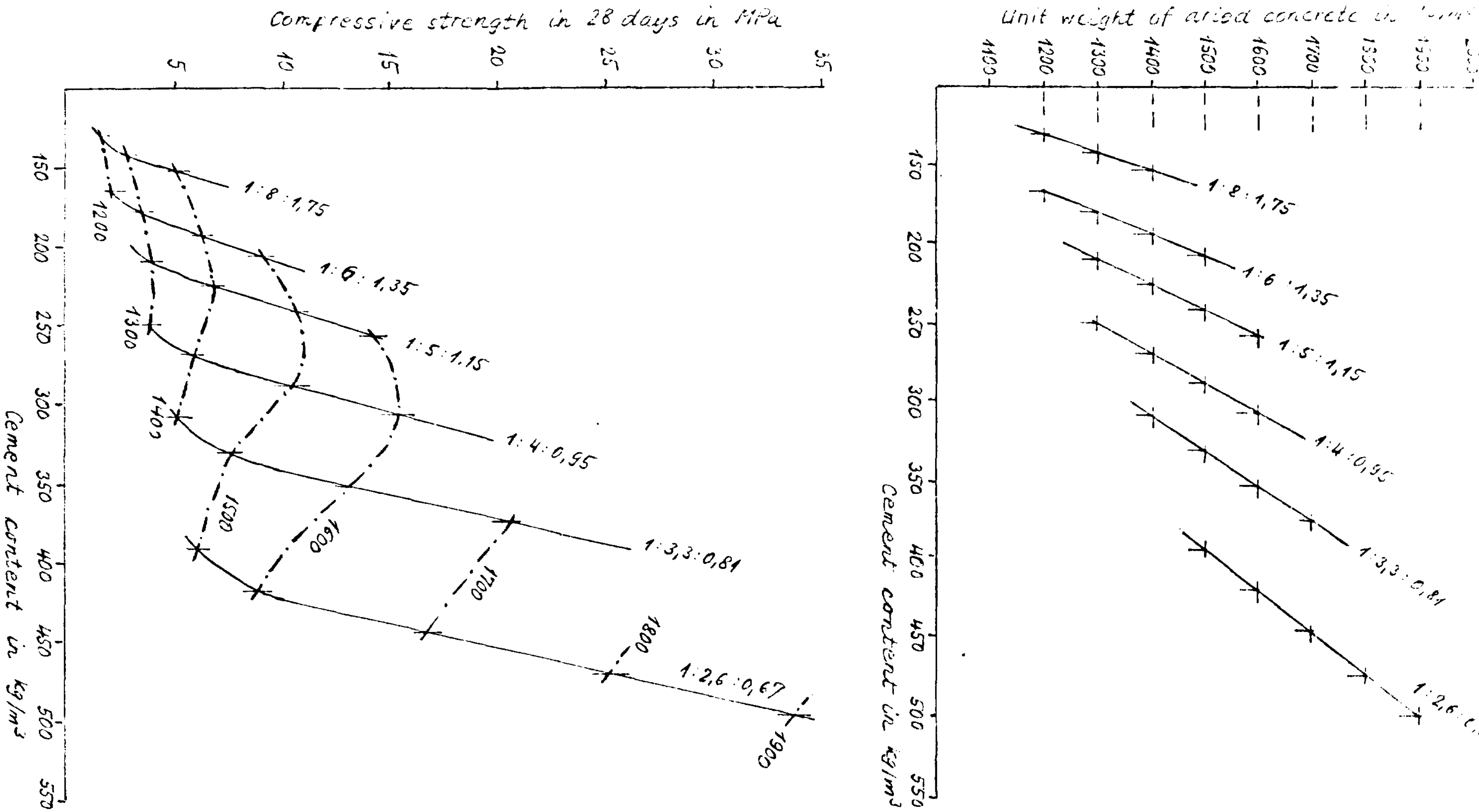
SECTION 2

F..re 5.


SECTION 1
Unit weight of dried concrete in kg/m³
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1:8:1,75
1:6:1,35
1:5:1,15
1:4:0,95
1:3,3:0,81
1:2,6:0,67
150
200
250
300
350
400
450
500
550
Cement content in kg/m³


Compressive strength in 28 days in MPa
35
30
25
20
15
10
5
1:8:1,75
1:6:1,35
1:5:1,15
1:4:0,95
1:3,3:0,81
1:2,6:0,67
1200
1300
1400
1500
1600
1700
1800
1900

SECTION 2



Relationship among cement content, mixing ratio, compacting method, compressive strength and unit weight of dried lightweight concrete

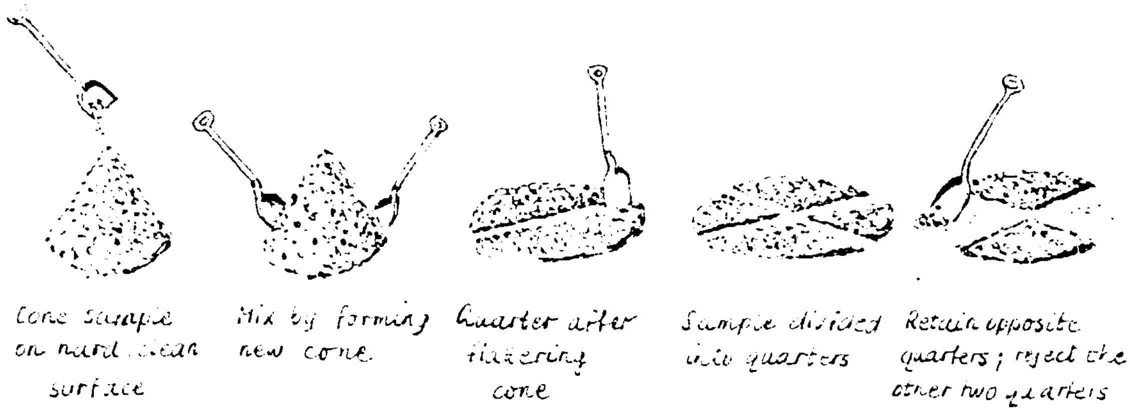


Figure 5.

SECTION 1

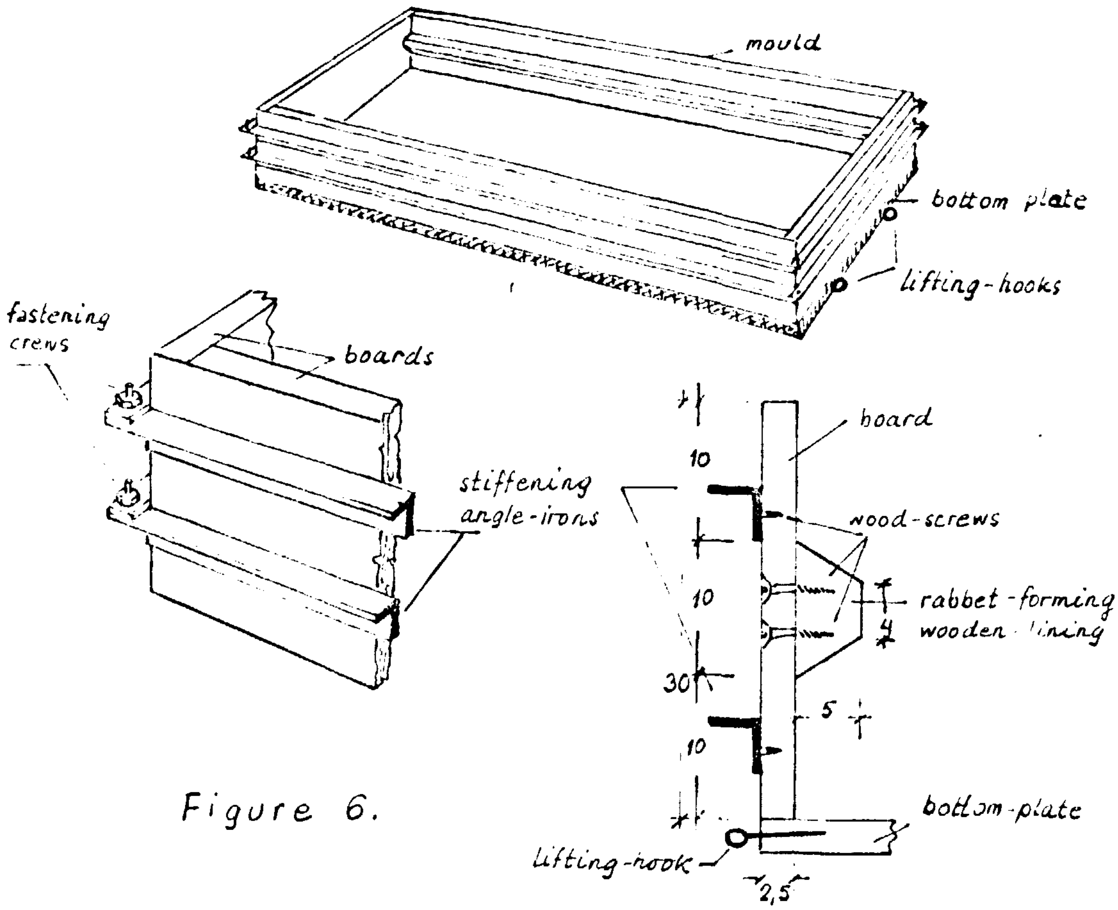


Figure 6.

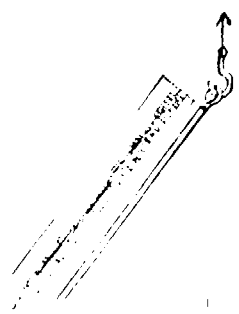


Figure 7.

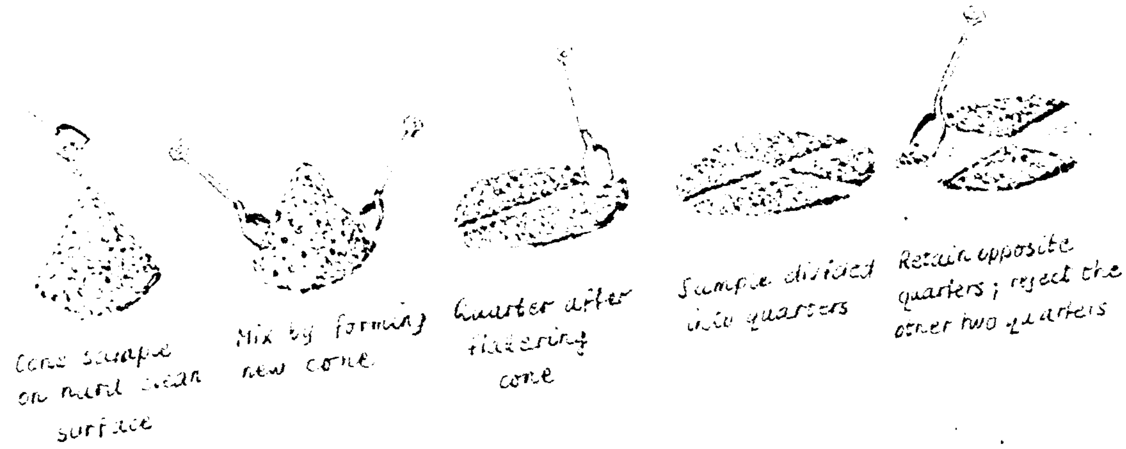


Figure 5.

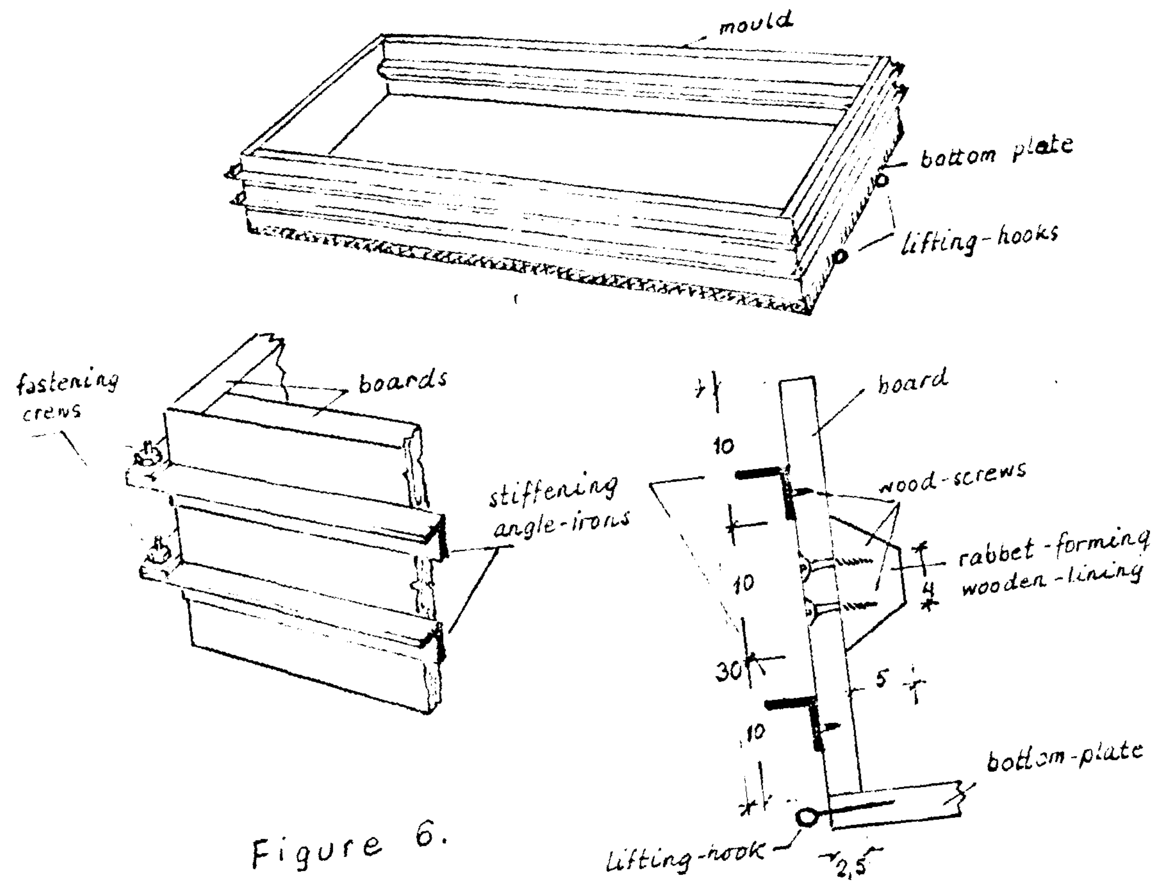


Figure 6.

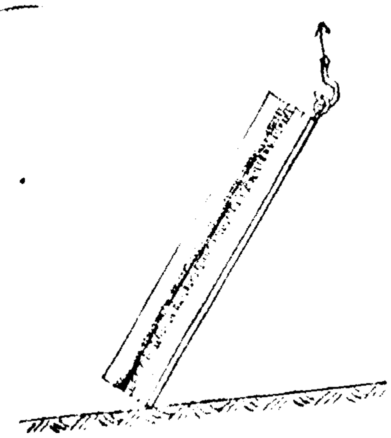


Figure 7.

SECTION 2

ANNEX No. 3

INVESTIGATION OF LIGHTWEIGHT AGGREGATE CONCRETES MADE WITH VOLCANIC MATERIALS ORIGINATED FROM DIFFERENT DEPOSITS

1.- INTRODUCTION

The requirements for the investigations are outlined in Annex No. 2, Chapters 3, 4.1 and 4.2.

The investigations were carried out in the laboratory of Ministry of Communication. This laboratory is equipped mainly for quality control of road constructions: testing soils, bitumens and concrete specimens made by the contractors for controlling purposes. The laboratory has the following equipments suitable to the concrete research work:

- ball mills for crushing fine materials
- balances and drying ovens
- sieves according to ASTM Standard
- eight cylinders of 15 cm in diameter and 30cm in height
- equipments for testing compressive strength of concrete specimens (hydraulic pressing machines) and for smoothing specimen surfaces by sulfur mortar.
- cutting machines for stones and concretes
- vibrating table for compaction of specimens (it was purchased on 19th September 1981, two weeks after the investigations started).

The collaborators of laboratory are skillful and well intentioned, well educated in quality control but untrained in concrete research work.

The laboratory is not equipped with crushers (roller or jaw crushers), screeners and mixer therefore crushing and screening aggregate furthermore mixing concrete had to be carried out by hand. In the first two weeks, the specimens were also compacted by hand.

Because of working by hand, the fulfilment of investigation program according to Annex No. 2 was impossible.

With regard to the lack of time, the expert had to be satisfied with a shorter program than was described in Annex No.2 Chapter 4.2 and Annex No. 1 Chapter 5.A respectively.

Therefore the results of investigations summarized in this Report can be evaluated only as informatory data and before final decision of utilization, further investigations have to be carried out with the best volcanic material. The goal of these further investigations is to get sufficient data for preparing Code Practice of making lightweight aggregate concrete including properties of these concretes.

2.- INVESTIGATION OF SAMPLE FROM HASSAKE

The sample arrived at the laboratory in big pieces of 30-50 kg.

According to Annex No. 2, Chapter 4.1, average sample. would have been necessary for the investigations.
It means that the material of about 300kg ought to be have crushed at the same time for getting sufficient average fractions. Presise data can be only get by testing material of average quality.
Because of the lack of storage place and crusher in the laboratory, crushing the whole sample was impossible. Therefore material had to be crushed from day to day in quantity enough for 4-6 specimens and after having screened, the mixing could be started.
Consequently, the results are not suitable for generalization.

2.1. AGGREGATE PROPERTIES

The crushed particles of the rock slumps were sieved on the following sieves:
0.25, 0.297, 0.42, 0.84, 2, 4.76, 12.7, and 38.1 mm (quadratic holes).
The pot for measuring bulk density was 2780cm^3 in volume and 202g in weight. The measurement of bulk density was repeated three times; the fractions were poured into the pot loosely and the surface of the heap was smoothed by steel ruler. The results of investigations can be seen as follows:

3/...

12.7-38.1 mm:	2379 g	2390 g	2397 g
	-202 g	-202 g	-202 g
	2177 g	2188 g	2195 g
4.76-12.7 mm:	2603 g	2617 g	2690 g
	-202 g	-202 g	-202 g
	2401 g	2415 g	2488 g
2-4.76 mm:	2822 g	2905 g	2995 g
	-202 g	-202 g	-202 g
	2620 g	2703 g	2793 g
0-2 mm:	3827 g	3850 g	3882 g
	-202 g	-202 g	-202 g
	3625 g	3648 g	3680 g

Bulk Densities:

12.7-38.1 mm: $\frac{2177 + 2188 + 2195}{3.2{,}78} = \frac{6560}{8.34} = 787\ kg/m^3$

4.76-12.7mm: $\frac{2401 + 2415 + 2488}{3.2{,}78} = \frac{7304}{8.34} = 876\ Kg/m^3$

2-4.76mm: $\frac{2620 + 2703 + 2793}{3.2{,}78} = \frac{8116}{8.34} = 973\ Kg/m^3$

0-2 mm: $\frac{3625 + 3648 + 3680}{3.2{,}78} = \frac{10953}{8.34} = 1313\ Kg/m^3$

The fraction of 0-2 mm was measured after 15 shaking:

Bulk density 1459 kg/m^3

For investigating water absorption, 2-2 kgs were weighed from the sieved fractions, furthermore aggregate mixture was composed from the fractions as follows:

35 pct by W. of 0 - 2 mm
25 pct by W. of 2 - 4.76 mm
20 pct by W. of 4.76 - 12.7 mm
20 pct by W. of 12.7 - 38.1 mm

Weight of aggregate mixture was 3000 g.

When the weighted samples were poured into the water, the height of water surface was 2 cm and it was increased with 2 cm in every 5 minutes.

4/...

Water absorption was measured after 0.5 and 1 hour. The results of water absorption investigation were as follows:

Fraction	Weight of samples in g			Water absorption in pct by W.	
	Before saturation	After 0.5 hour	After 1 hour	after 0.5 hour	After 1 hour
0 2	2000	2536	2547	26.8	27.4
2 -4.76	2000	2356	2310	18.3	15.5
4.76-12.7	2000	2291	2291	14.6	14.6
12.7-38.1	2000	2280	2318	14.0	15.9
mixture	3000	3569	3555	19.0	18.5

<u>Control</u> The water absorption of the mixture can be calculated from that of the fractions. After having calculated, the results are as follows:

Fraction in mm	Part by weight	Water absorption in 0.5h	Water absorption in 1h	2 x 3	2 x 4
1	2	3	4		
0 -2	0.35	26.8	27.4	7.38	9.59
2 -4.76	0.25	18.3	15.5	4.58	3.89
4.76 -12.7	0.20	14.6	14.6	2.92	2.92
12.7 -38.1	0.20	14.0	15.9	2.80	3.18
				19.68	19.58

It can be seen that

- between water absorptions in 0.5 h and in 1 h are practically no differences
- the result of investigation of 2-4.76mm fraction in 0.5 h is certainly not correct, therefore instead of 18.3 pct by W it can be calculated with 15.5 pct by W.

On the basis of this calculation, the water absorption of the mixed aggregate in 0.5 h comes to 19 pct by W. To the concrete composition, this water absorption should be taken in account.

For investigation of <u>unit weight</u> of rock, one rock slump was weighed (air dry weight) and placed into a pot filled up to 2cm with water.

Water surface was heighed with 2cm in every 5 minutes. After two days, the volume of the slump was measured by water displacement:

Air dry weight of the slump	7493 g
Weight of the saturated slump	9334 g
Volume of the slump	52.3 dm^3
Unit weight of the rock	1432 kg/dm^3

For investigating the grading of the fraction 0-2mm, 2000 g of material was weighed and sieved.. The results are as follows:

0 - 0.25 mm	235 g	11.8	pct by weight
0.25 - 0.294 mm	60 g	3.0	" "
0.297- 0.297 mm	123 g	6.2	" "
0.42 - 0.84 mm	513 g	25.7	" "
0.84 - 2.0 mm	1069g	53.3	" "

2.2. INVESTIGATION OF CONCRETE MIXTURES

Aggregate mixtures of three gradings were used to the investigations.

The first serie was made with aggregate of maximum grain size of 38.1 mm. Quantities of fractions: 35pct of 0-2 mm; 25pct of 2-4.76mm; 20 pct of 4.76-12.7mm; 20 pct of 12.7-38.1mm.

The second serie was made with aggregate of maximum grain size of 12.7mm. Quantities of fractions: 50pct of 0-2mm ; 25 pct of 2-4.76mm and 25 pct of 4.76-12.7 mm.

To the third serie, limestone sand of 0-0.42mm was used instead of 0-2mm crushed volcanic material.

The gradings of the three series can be seen in Fig. 1.

After having weighed the different fractions, they were poured into a metal tray and mixed by hand, until the colour of the mixture became uniform. The mixing was continued by hand during spreading with water. After finishing the mixing, it was waited for 10 minutes that the aggregate would absorb part of mixing water.

6/...

The concrete mixture was poured into the mould partly without compaction and partly with compaction by stamper (which is otherwise used to Proctor-investigations). The compacted specimens were stamped in four layer, every layer with 15 blows. Specimens' surfaces were smoothed with steel ruler.

The mixing ratios of mixtures and the unit weight and compositions of fresh concretes can be seen in Table 1.

To get exact data, at least 3 specifimens would have had to be made, but because of lack in crusher, screener, mixer and vibrator on the one hand and due to the limited number of moulds and small quantity of volcanic material on the other, only two specimens were made from one mixture.

Therefore the results of investigations are only informatory.

It should be emphasized that in spite of circumstances, the results of investigation can be regarded as correct, owing to devoted work of the staff of the laboratory.

For compacting specimens, steel bar and stamper were available. If the concrete had been compacted by vibrating table or primarily by vibrators, higher unit weights could have been reached.

Testing of compressive strength was carried out in 14 days. Usually the compressive strength of 28 days is the standard one, but the short time of expert needed earlier investigations. The specimens were stored in moulds under wet clothes in the first day, then - after taking them out of the moulds - in water and and they were taken out from the water in 10-12 days and before testing, their surfaces were smoothed with sulfur-mortar.

Results of testing compressive strength can be seen in Table 2.

7/...

From data of Table 1, the relationship between cement content and unit weight of fresh concrete depending on mixing ratios (according to Annex 2, Chapter 3.) is plotted in Figure 2.

From data of Tabel 2, the relationship between cement content and dry concrete unit weight depending on mixing ratios is plotted in Fig. 3.

The relationship between compressive strength and unit weight of dry concrete can be seen in Fig. 4. Since this relationship is generally parabolic, Fig. 4 is plotted according to parabolic function. Naturally this is an approach but it can be accepted for practical purposes.

The practical purpose is now the drawing relationships according to Annex 2, Chapter 5. In figures 5 and 6 the range of compressive strength can be seen for concretes of different mixing ratios, depending on their cement contents. For drawing these Figures, the date of Figure 4 can be utilized.

Fig. 5 is important for regulation of concrete technology and Fig. [illegible] is suitable for design of concrete structures. We shall come back to that later.

3.- INVESTIGATION OF SAMPLE FROM RACCA

The sample arrived at the laboratory in rock slumps of 5-15 kg. Crushing the material of Racca was the same as that of Hassake i.e. by hand from day to day.

3.1. AGGREGATE PROPERTIES

The particles of the crushed rock were sieved on the following sieves: 0.25; 0.297; 0.42; 0.84; 2; 4.76; 1[illegible]7; and 25.4 mm. (quadratic holes).

The pot of measuring bulk density was 930 cm^3 in volume and 4275g in weight, the measuring was repeated three times. The results of investigations were as follows:

12.7 - 25.4 mm:	5040	5100	5000	765+825+725 / 3.0,93 = 830 kg/m³
	-4275	-4275	-4275	
	765	825	725	
4.76- 12.7 mm:	5135	5175	5150	860+900+875 / 3.0,93 = 944 kg/m³
	-4275	-4275	-4275	
	860	900	875	
2 - 4.76 mm:	5225	5230	5240	950+955+965 / 3.0,93 = 1029 kg/m³
	-4275	-4275	-4275	
	950	955	965	
0 - 2 mm:	5375	5385	5370	1100+1110+1095 / 3.0,93 = 1185 kg/m³
	-4275	-4275	-4275	
	1100	1110	1095	

Aggregate mixture was composed from fractions as follows:

0	-	2 mm	35 pct by weight
2	-	4.76 mm	25 pct by weight
4,76	-	12.7 mm	20 pct by weight
12.7	-	25.4 mm	20 pct by weight

Bulk Density of mixture:

5360	5360	5340	1085+1085+1065 / [illegible] = 1160 kg/m³
-4275	-4275	-4275	
1085	1085	1065	

The bulk density of the mixture was also measured after 15 shaking, the results: 1274 kg/m³

The investigations of water absorption were carried out with the mixture. After 0.5 hour the water absorption was 14.4 pct by weight.

For measuring unit weight of rock, three rock slumps were weighed (air dry weight) and placed into a pot (the method of investigation is described in Chapter 2.1)

Air dry weight of the slumps	: 4141 g
Weight of the saturated slumps	: 4743 g
Volume of the slumps	: 2483 cm³
Water absorption of the rock	: 14.5 pct by weight
Unit weight of the rock	: 1668 kg/m³

For investigating the grading of the fraction 0-2mm, 2000 g material was weighed and sieved. The results are as follows:

0	- 0.25	mm	217	g	10.9	pct by weight
0.25	- 0.297	mm	20	g	1.0	pct by weight
0.297	- 0.42	mm	55	g	2.7	pct by weight
0.42	- 0.84	mm	390	g	19.5	pct by weight
0.84	- 2	mm	1319	g	65.9	pct by weight

3. INVESTIGATION OF CONCRETE MIXTURES

Aggregate mixtures of two gradings were used to the investigations.
The first serie was made with aggregate of maximum grain size of 25.4mm: 35 pct of 0-2mm; 25 pct of 2-4.76mm; 20 pct of 4.76-12.7mm; 20 pct of 12.7-25.4 mm.

The second serie was made with aggregate of maximum grain size of 12.7mm: 45 pct of 0-2mm; 30 pct of 2-4.76mm and 25 pct of 4.76-12.7 mm.

The gradings of these two series can be seen in Fig. 7

The method and circumstances of making concrete were the same as were written in Chapter 2.1.

The mixing ratios of the mixtures, futhermore the unit weights and compositions of fresh concretes can be seen in Table 3. The data represent results of two specimens. Results of testing compressive strength in 14 days can be seen in Table 4.

From data of Table 3., the relationship between cement content and unit weight is plotted in Fig. 8 from data fo Table 4, the relationship between dry unit weight and compressive strength was drawn and it can be seen in Fig. 9. This figure was utilized for plotting relationship between cement content and compressive strength, according to Figures 10 and 11.

10/...

4.- INVESTIGATION OF SAMPLE FROM SHAHBA

The sample arrived at the laboratory in grains with maximum grain size of 12.7mm according to its original state. Crushing material was not necessary.

4.1: AGGREGATE PROPERTIES

The material particles were sieved on the following sieves:

0.25; 0.12; 0.84; 2; 4.76; and 12.7 mm

The pot for measuring bulk density was 956 cm³ in volume and 4283 g in weight, the measuring was repeated three times with each fraction. The results of investigation are as follows:

4.76 – 12.7 mm:	4815 g	4827 g	4799 g	$\frac{532+544+516}{3 \cdot 0,956}$ =555 kg/m³
	-4283	-4283	-4283	
	532 g	544 g	516 g	
2 – 4.76 mm:	[illegible]	4845 g	4857 g	$\frac{535+562+574}{3 \cdot 0,956}$ =600 kg/m³
	-4283	-4283	-4283	
	535 g	562 g	574 g	
0 – 2 mm:	4883 g	4881 g	4877 g	$\frac{600+598+594}{3 \cdot 0,956}$ =625 kg/m³
	-4283	-4283	-4283	
	600 g	598 g	594 g	

Aggregate mixture was composed from the fractions as follows:

0 – 2 mm	50 pct by weight
2 – 4.76 mm	25 pct by weight
4.76 – 12.7 mm	25 pct by weight

Bulk density of mixture:

4912 g	4898 g	4918 g	$\frac{629+615+635}{3 \cdot 0,956}$ = 655 kg/m³
-4283	-4283	-4283	
620 g	615 g	635 g	

The investigations of water absorption were carried out with the mixture. After 0.5 hour the water absorption was 19.2 pct by weight.

12/...

Measuring unit weight of rock was not possible because rock slumps were not available.

For investigation of the grading of fraction 0-2mm, 2000 g material was weighed and sieved. The results are as follows:

0 -- 0.25 mm	369 g	18.5 pct by weight
0.25 - 0.42 mm	58 g	2.9 pct by weight
0.42 -- 0.84 mm	478 g	23.9 pct by weight
0.84 -- 2 mm	1095 g	54.7 pct by weight

4.2. INVESTIGATION OF CONCRETE MIXTURES

Aggregate mixtures of two gradings were used to the investigations.

The first serie was composed with aggregate of maximum grain size of 12.7mm: 50 pct of 0-2mm; 25 pct of 2-4.76 mm and 25 pct of 4.76-12.7mm.

To the second serie was used material of original grading (maximum grain size is 12.7 mm).

The gradings of these two series can be seen in Fig.12

The method and circumstances of making concrete were the same as was described in Chapter 2.1

Mixing ratios of the mixtures, furthermore the unit weights and compositions of fresh concretes can be seen in Table 5. The data represent results of two specimens. Results of testing compressive strength can be seen in Table 6.

From data of Table 5, relationship between cement content and unit weight is plotted in Fig. 13. From data of table 6, the relationship between dry unit weight and compressive strength was drawn and it can be seen in Fig. 14.

This figure was utilized for plotting relationship between cement content and compressive strength, according to Figures 15 and 16.

5.- EVALUATION OF TEST RESULTS

The bulk densities, unit weights and water absorptions of different volcanic materials tested at these investigations can be seen in Table 7. As standard value, the bulk density measured on particles of 4.76-12.7 mm can be used. According to the results, bulk densities are as follows: (in order):

Shahba deposit	:	555 kg/m^3
Hassake deposit	:	876 kg/m^3
Racca deposit	:	944 kg/m^3

Unit weight of fresh and dry concretes had the following limits:

Deposit	Unit weight in Kg/m^3	
	of fresh concrete	of dry concrete
Shahba	639 - 1458	758 - 1326
Hassake	861 - 2034	761 - 1867
Racca	1263 - 2040	1177 - 1891

The compressive strength of different concretes was investigated in different days owing to the official holidays between 7-13 October. Therefore, for evaluating compressive strengths, hardening process of cement used to the investigations has to be known.

This process can be seen in Fig. 17 according to information obtained from G.O.C. On the basis of this figure, percent of compressive strength in the strength of 28 days - since the relationship between 7 and 28 days is logarithmic linear - is as follows:

$$pct = 100 - \frac{38.5}{lg\,28 - lg\,7} \cdot (lg\,28 - lgx)$$

where x = day of the investigation (between 7 and 28 days)

Examples

Percent of compressive strength in 14 days

$$100 - \left[\frac{38.5}{lg28-lg7}(lg\,28-lg14)\right] = 100 - (63.95 \; ; \; 0.301) =$$

$$100-19.25=80.75$$

Percent of compressive strength in 15 days

$$100-\left[\frac{38.5}{lg28-lg7}(lg\ 28-lg\ 15)\right]=100(63.95:0.271)=100-17.33=82.67\ pct$$

Some data - for facilitating the evaluation - are as follows:

Day	13	14	15	16	17	18	19	20
Pct	78.29	80.75	82.67	84.46	86.14	87.73	89.23	90.66

By means of the above values, the tested compressive strengths can be transformed to compressive strengths in 28 days. E.g. specimens of Signe 1 had compressive strength in 14 days 3.7 MPa, their compressive strength in 28 days - in all likelihood - will be 3.7:0.8075 = 4.6 MPa, while specimens of Signe 4 were investigated in 16 days, therefore their compressive strength in 28 days can come to 20.0: 0.8446 = 23.7 MPa.

Further on, the compressive strength in 28 days are given by means of this transformation. The data can be seen in Table 8.

From the data of Table 8 and from that of Tables 2,4 and 6 relationship between dry concrete unit weight and compressive strength in 28 days (calculated) can be seen in Fig. 18 depending on the materials investigated from different deposits.

According to Fig. 18 for making concrete of 1200-1300kg/m^3 in dry unit weight, material from Shahba is the most suitable (compressive strengths in 28 days are about 5-8 MPa). For concrete of 1600-1800 kg/m^3 in dry unit weight, both materials from Hassake and Racca can be employed (compressive strengths in 28 days are about 7-16 MPa)

It can be stated that the materials used to investigations reported are suitable for making lightweight aggregate concretes:

- for load-bearing and thermal insulating concretes from Shahba materials,
- for load-bearing concretes from materials of Hassake and Racca.

On the basis of the results, continuing investigations can be suggested.

15/...

Table 1. Fresh concretes' data of material from Hassake

Serie	Signe	Mixing ratio C : A : W	Compaction	Unit weight of fresh concrete kg/m³	Cement	Aggregate	Water	Day of making specimens
					content, kg/m³			
1	1	1 : 6 : 1,14	with stamper	1912	235	1409	268	08.09.
	6		without	861	106	634	121	13.09.
	2	1 : 4 : 0,76	with stamper	1902	330	1321	251	08.09.
	7		without	1443	251	1002	190	13.09.
	3	1 : 3 : 0,57	with stamper	2031	444	1334	253	09.09.
	8		without	1521	333	998	190	13.09.
	4	1 : 2,88 : 0,57	with stamper	2034	457	1316	261	10.09.
	9		without	1583	357	1028	203	14.09.
2	10	1 : 6 : 0,79	with stamper	1858	238	1431	189	16.09.
	10		without	1303	167	1004	132	16.09.
	11	1 : 4 : 0,72	with stamper	1862	326	1302	234	19.09.
	11		without	1350	236	944	170	19.09.
3	5	1 : 4 : 0,67	with stamper	2173	383	1533	257	12.09.

Table 2. Testing data of concretes made with material from Hassake

Serie	Signe	Unit weight at testing kg/m³	Dry unit weight* kg/m³	Compressive strength MPa	Day of testing
1	1	1851	1690	3,7	22.09.
	6	1353	761	0,7	27.09.
	2	1854	1717	7,6	22.09.
	7	1394	1303	1,4	27.09.
	3	2005	1867	14,0	23.09.
	8	1496	1398	3,3	27.09.
	4	2000	1864	20,0	26.09.
	9	1560	1456	4,9	29.09.
2	10	1832	1717	8,3	30.09.
	10	1262	1204	0,6	30.09.
	11	1804	1693	8,7	03.10.
	11	1289	1227	1,0	03.10.
3	5	2106	1933	20,4	26.09.

*Dry unit weight of concrete can be calculated: it can be supposed, with good approach, that the cement binds chemically 20 pct of its weight from water. Therefore e.g. dry unit weight of specimens Signe 1. is: $235 + 1409 + 0,2 \cdot 235 \approx 1690$ kg/m³

Table 3. Fresh concretes' data of material from **Racca**

Serie	Signe	Mixing ratio C : A : W	Compaction	Unit weight of fresh concrete kg/m³	Cement	Aggregate	Water	Day of making specimens
					content, kg/m³			
1	12	1 : 6 : 0,87	with stamper	1714	218	1308	188	21.09.
	12		without	1330	169	1015	146	21.09.
	13	1 : 4 : 0,58	with stamper	1763	316	1265	182	21.09.
	13		without	1263	226	905	131	21.09.
	14	1 : 3 : 0,53	with stamper	2040	450	1351	239	23.09.
	14		without	1813	400	1201	212	23.09.
	15	1 : 2,5 : 0,44	with stamper	2003	508	1270	225	23.09.
	15		without	1565	397	992	176	23.09.
2	16	1 : 6 : 0,87	with stamper	1729	220	1318	191	26.09.
	16		without	1487	189	1134	164	26.09.
	17	1 : 3 : 0,50	with stamper	1894	421	1263	211	26.09.
	17		without	1356	301	904	151	26.09.

Table 4. Testing data of concretes made with material from Racca

Serie	Signe	Unit weight at testing kg/m³	Dry unit weight* kg/m³	Compressive strength MPa	Day of testing
1	12	1675	1570	3,3	05.10.
	12	1282	1218	0,5	05.10.
	13	1745	1644	8,0	05.10.
	13	1240	1177	0,7	05.10.
	14	2019	1891	19,8	13.10.
	14	1702	1681	3,5	13.10.
	15	1980	1880	17,4	13.10.
	15	1529	1468	3,6	13.10.
2	16	1674	1582	4,6	13.10.
	16	1430	1361	1,4	13.10.
	17	1877	1768	14,5	13.10.
	17	1318	1265	1,6	13.10.

* Calculated data, see Table 2.

Table 5. Fresh concretes' data of material from Shahba

Serie	Signe	Mixing ratio C:A:W	Compaction	Unit weight of fresh concrete kg/m³	Cement	Aggregate	Water	Day of making specimens
					content, kg/m³			
1	18	1: 5 :0,94	with stamping	1198	173	863	162	27.09.
	18		without	873	126	629	118	27.09.
	19	1:3,5:0,7	with stamping	1232	237	829	166	28.09.
	19		without	839	161	565	113	28.09.
	20	1:2,5:0,6	with stamping	1430	349	872	209	28.09.
	20		without	976	238	595	143	28.09.
	21	1:2,2:0,54	with stamping	1458	390	858	210	29.09.
	21		without	941	252	553	136	29.09.
2	22	1:3,5:0,7	with stamping	1241	239	835	167	29.09.
	22		without	[illegible]56	167	583	116	29.09.

Table 6. Testing data of concretes made with material from Shahba

Serie	Signe	Unit weight at testing kg/m³	Dry unit weight* kg/m³	Compressive strength MPa	Day of testing
1	18	1140	1071	1,1	13.10.
	18	817	780	0,1	13.10.
	19	1198	1113	1,9	13.10.
	19	789	758	0,1	13.10.
	20	1405	1291	6,9	13.10.
	20	945	881	0,5	13.10.
	21	1416	1326	6,8	13.10.
	21	945	855	0,6	13.10
2	22	1206	1122	2,4	13.10.
	22	812	783	0,1	13.10.

* Calculated data, see Table 2.

Table 7. Summarizing of investigated aggregate properties

Deposit	Unit weight of rock in kg/m³	Water absorption after 0,5 hour in pct by W.	Bulk density in kg/m³ measured on					
			0-2	2-4,76	4,76-12,7	12,7-25,4	12,7-38,1	mixture
			mm particles					
Shahba	-	19,2	625	600	555	-	-	655
Hassake	1432	19,0	1313	973	876	-	787	-
Racca	1662	14,4	1185	1029	944	830	-	1160

Table 8. Compressive strength transformed to 28 days

Signe	Age day	Divisor	Tested	For 28 days transformed	Signe	Age day	Divisor	Tested	For 28 days transformed
			compr. strength in MPa					compr. strength in MPa	
Hassake deposit					Continuation of Racca deposit				
1	14	0,8075	3,7	4,6	14	20	0,9066	19,8	21,8
6	14		0,7	0,9	14	20		3,5	3,9
2	14		7,6	9,4	15	20		17,4	19,2
7	14		1,4	1,7	15	20		3,6	4,0
3	14		14,0	17,3	16	17	0,8614	4,6	5,3
8	14		3,3	4,1	16	17		1,4	1,6
4	16	0,8446	20,0	23,7	17	17		14,5	16,8
9	15	0,8267	4,9	5,9	17	17		1,6	1,9
10	14	0,8075	8,3	10,3	Shuhba deposit				
10	14		0,6	0,7	18	16	0,8446	1,1	1,3
11	14		8,7	10,8	18	16		0,1	0,1
11	14		1,0	1,2	19	15	0,8267	1,9	2,3
5	14		20,4	25,3	19	15		0,1	0,1
Racca deposit					20	15		6,9	8,3
12	14	0,8075	3,3	4,1	20	15		0,5	0,6
12	14		0,5	0,6	21	14	0,8075	6,8	8,4
13	14		8,0	9,9	21	14		0,6	0,7
13	14		0,7	0,9	22	14		2,4	3,0
					22	14		0,1	0,1

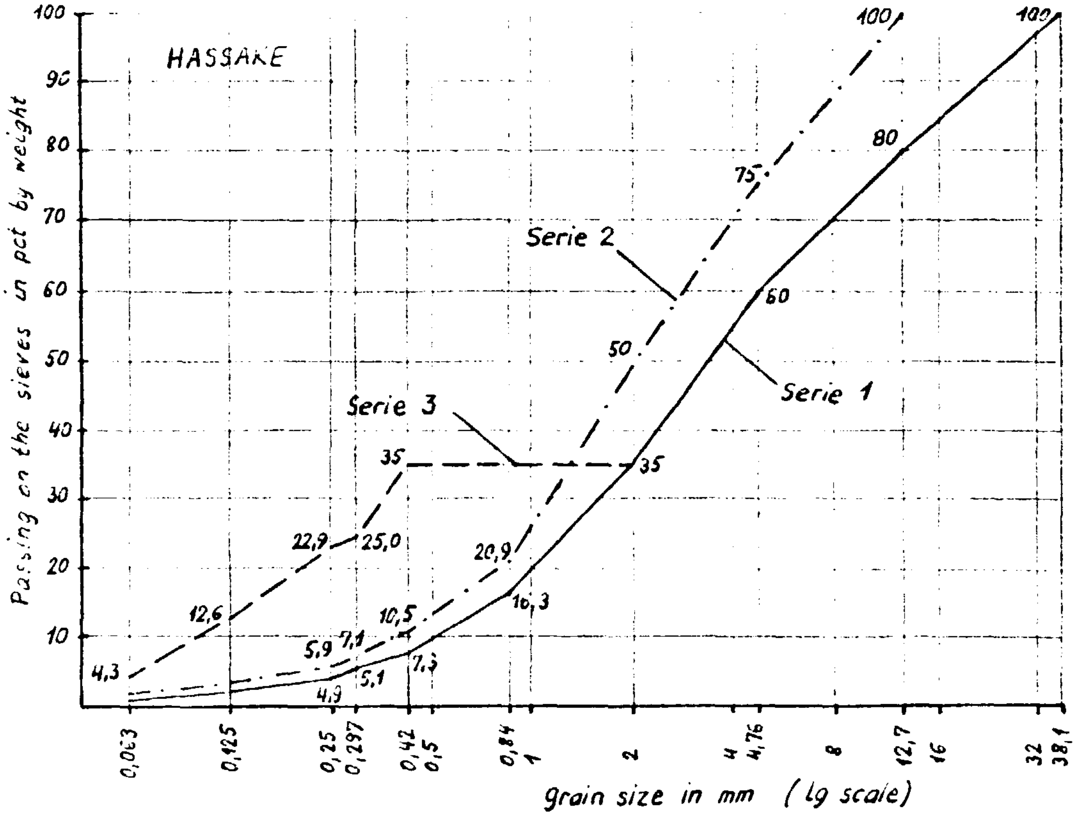


Figure 1. Grading of aggregate made from material of Hassake

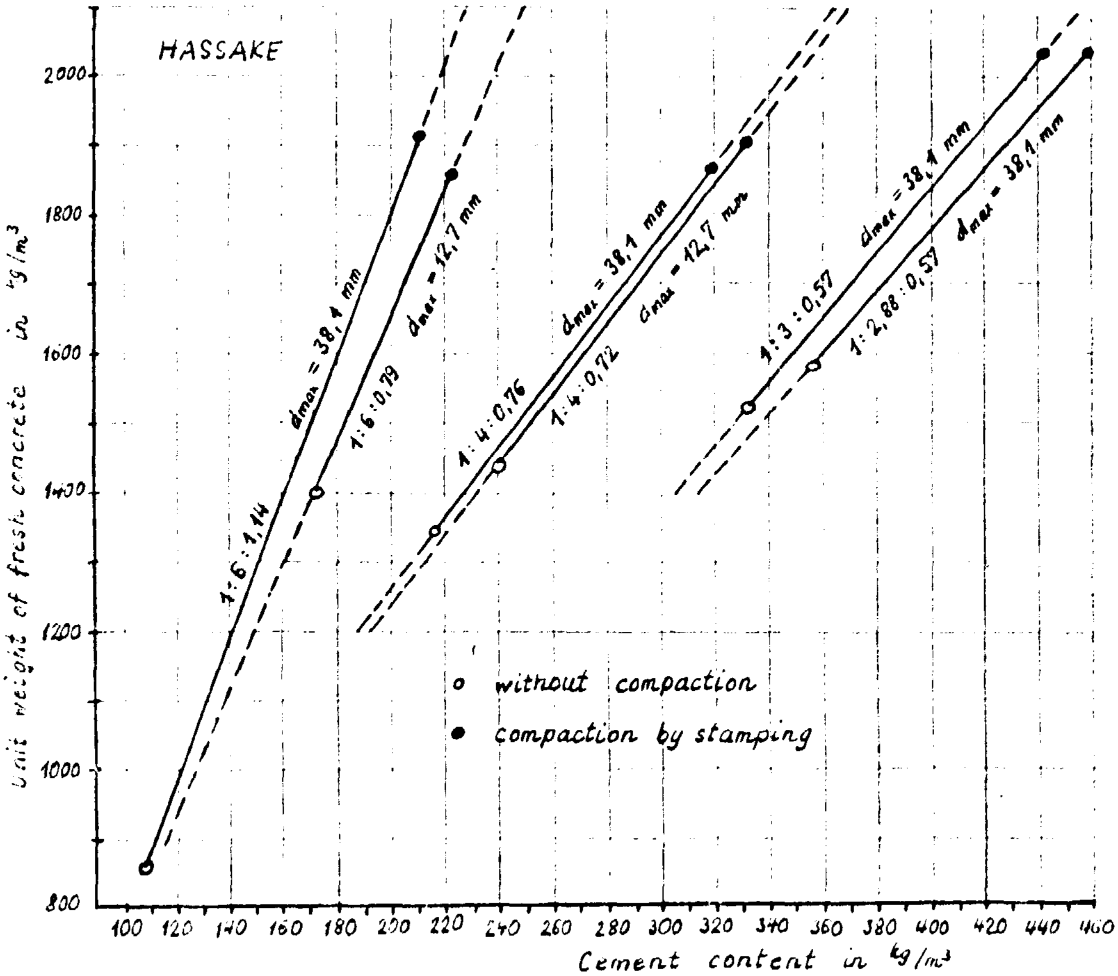


Figure 2. Relationship between cement content and fresh concrete unit weight depending on the mixing ratio and compaction

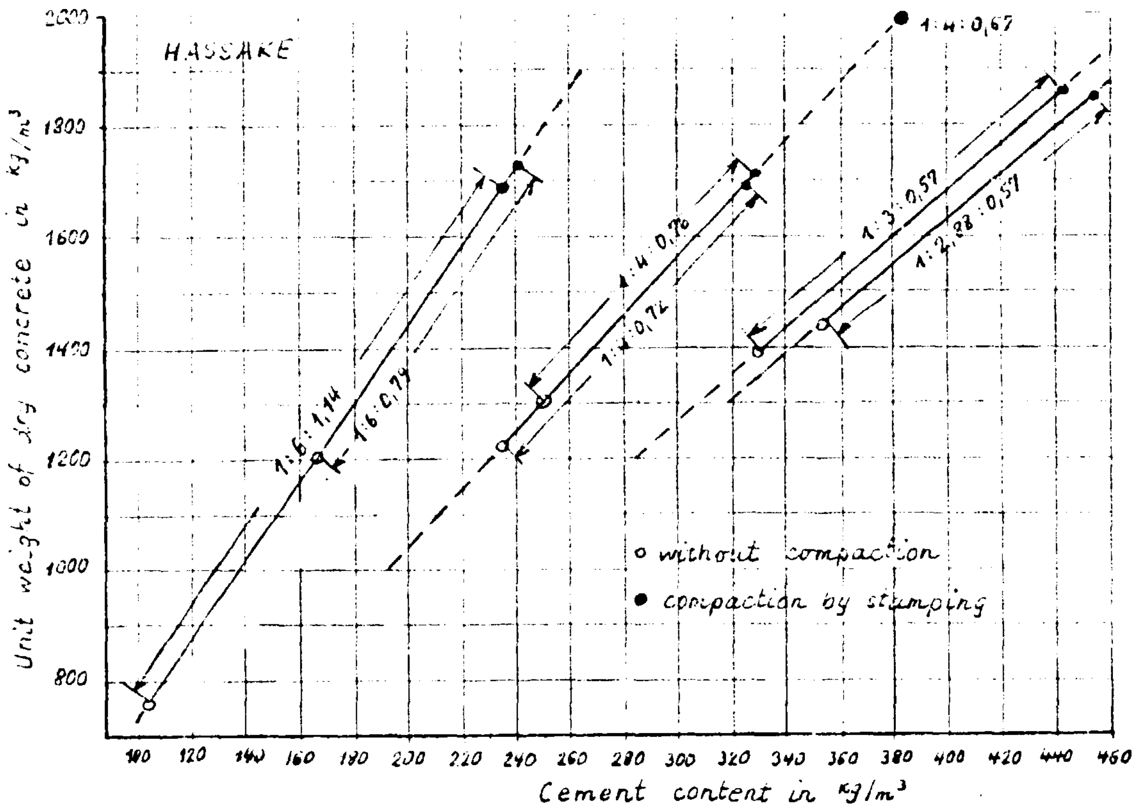


Figure 3. Relationship between cement content and unit weight of dry concrete depending on mixing ratio and compaction

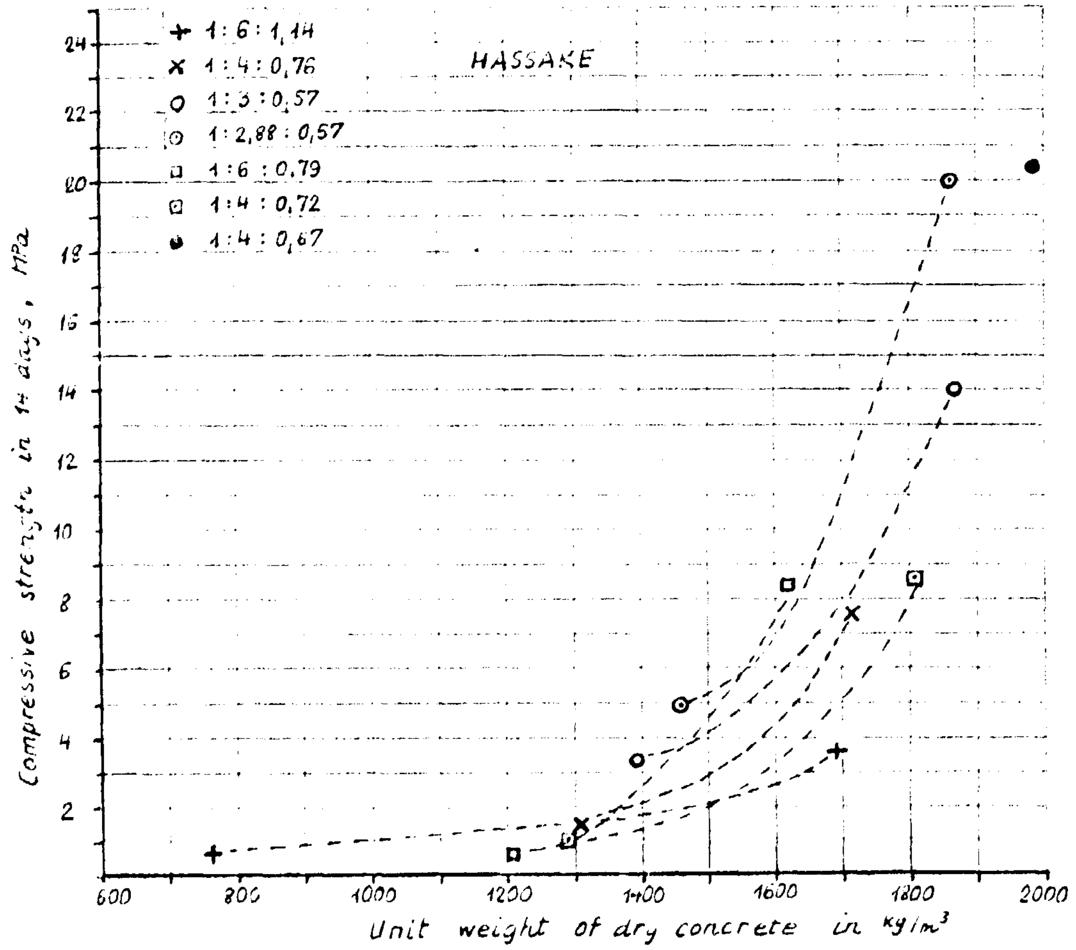


Figure 4. Relationship between unitn weight and compressive strength depending on mixing ratio

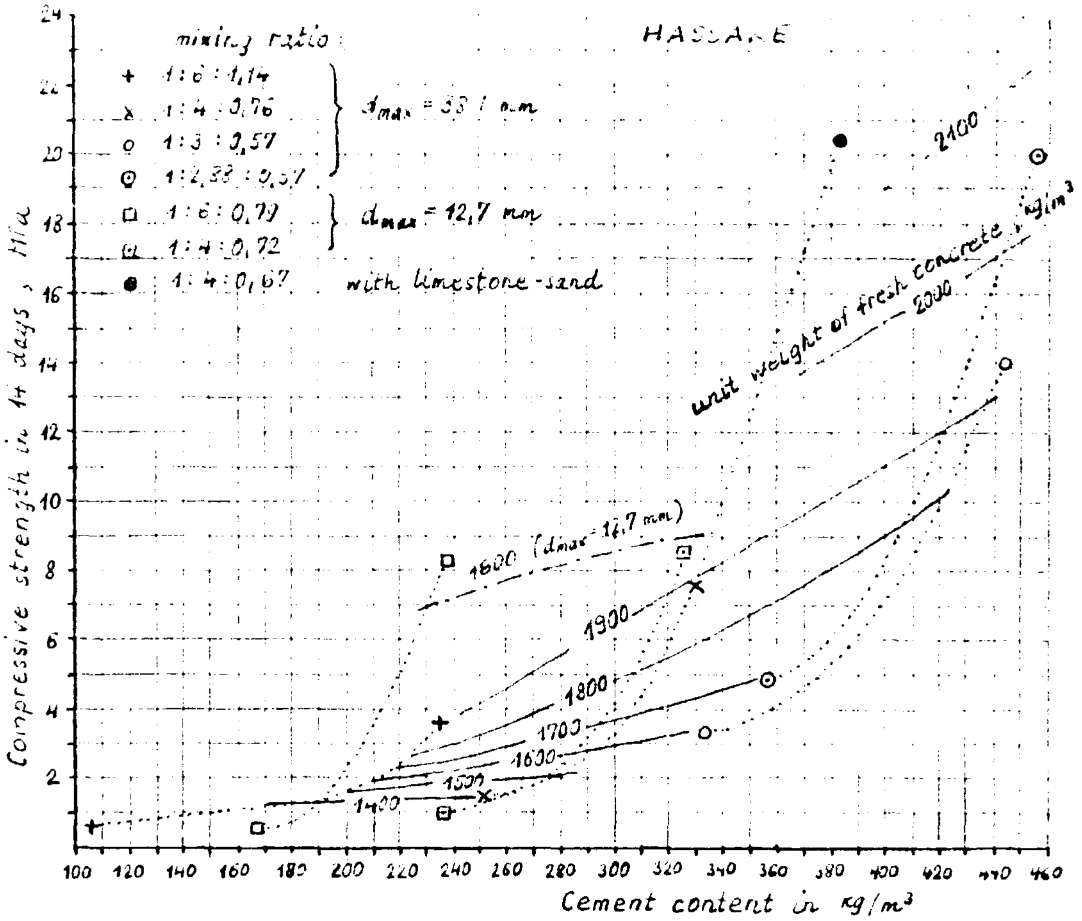


Figure 5. Relationship between cement content and compressive strength depending on unit weight of fresh concrete

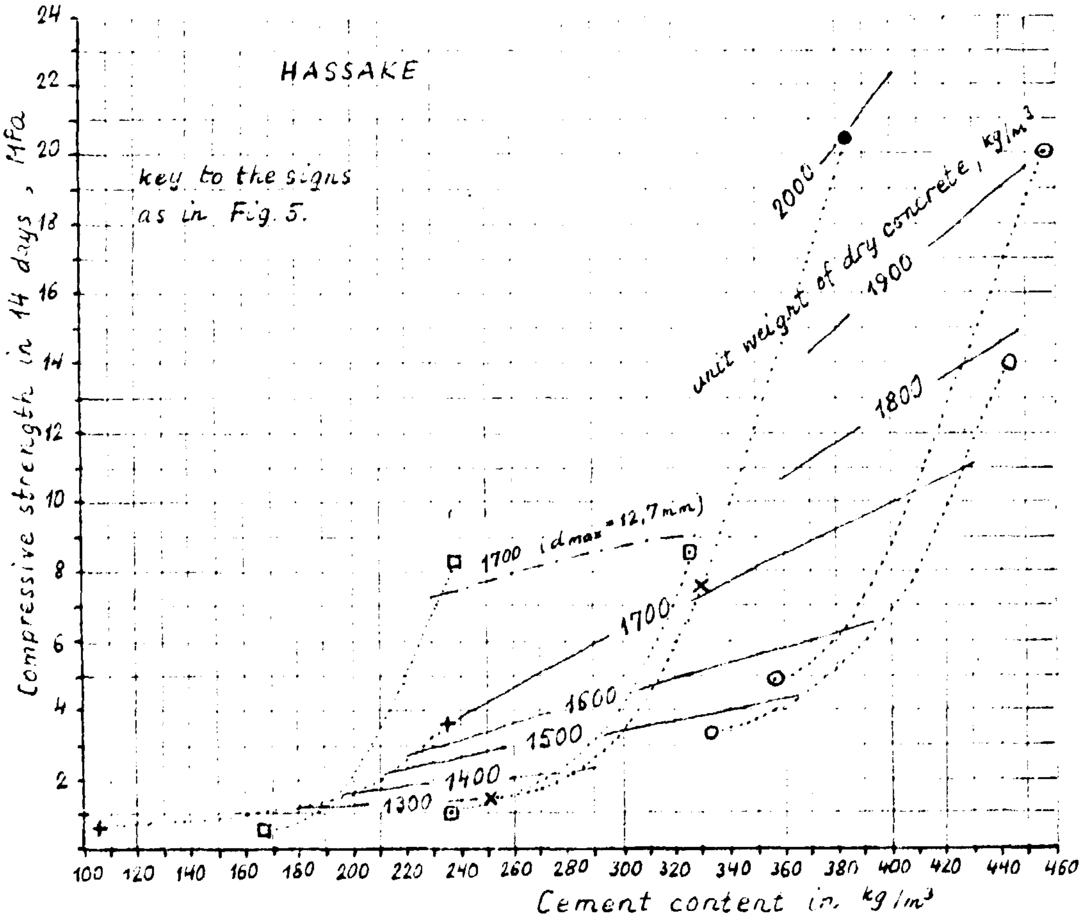


Figure 6. Relationship between cement content and compressive strength depending on unit weight of dry concrete

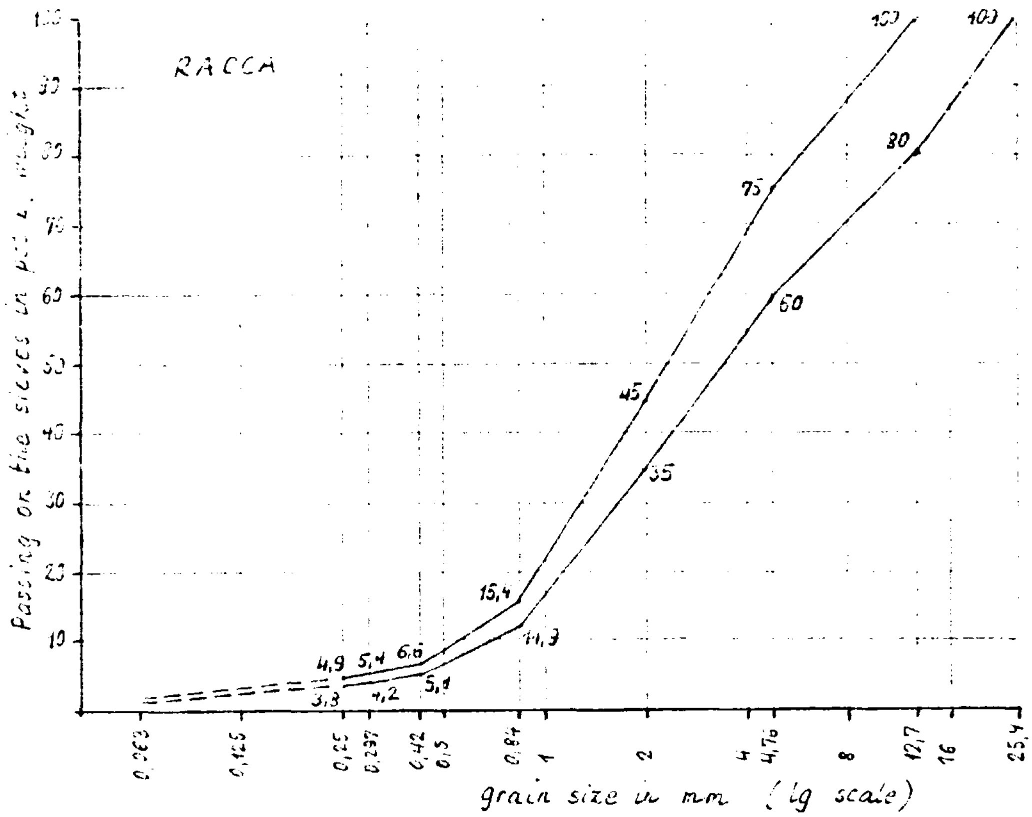


Figure 7. Grading of aggregate made from material of Racca

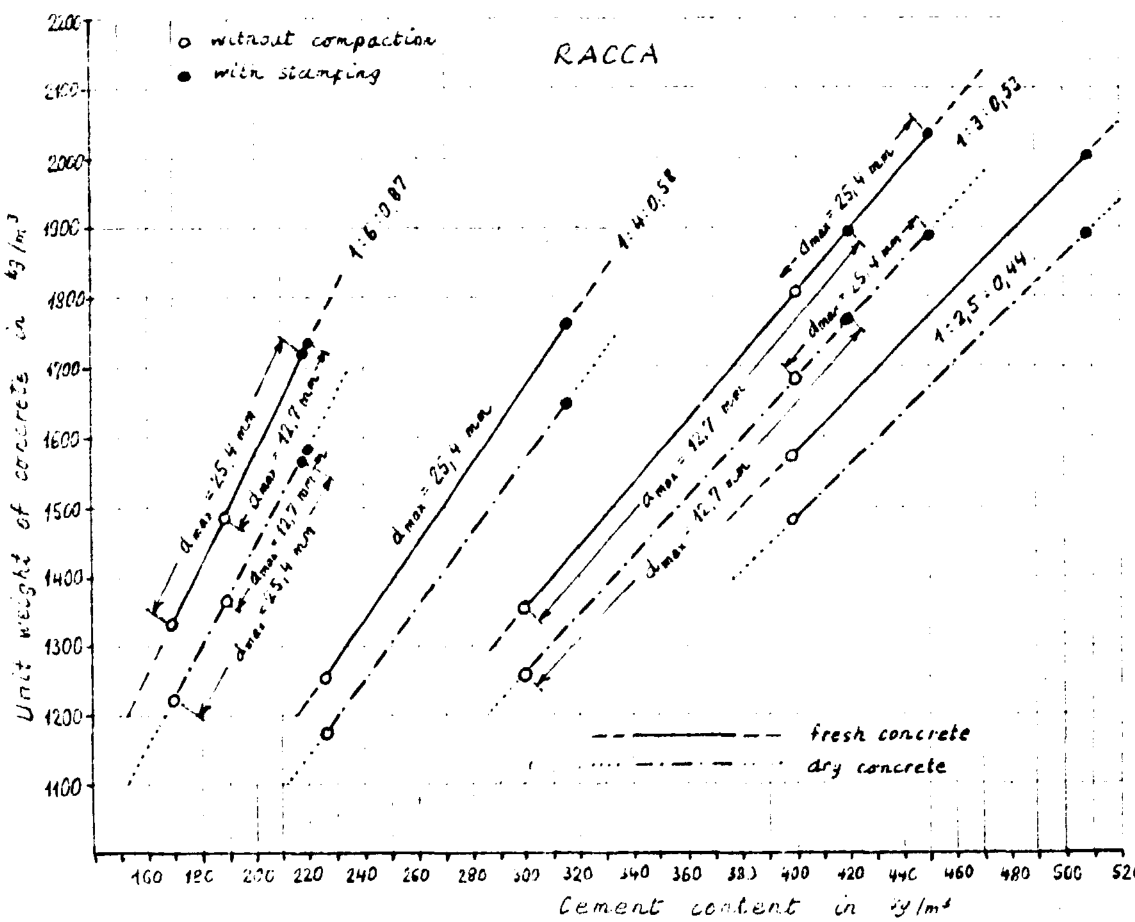


Figure 8. Relationship between cement content and unit weight, depending on mixing ratio and compaction

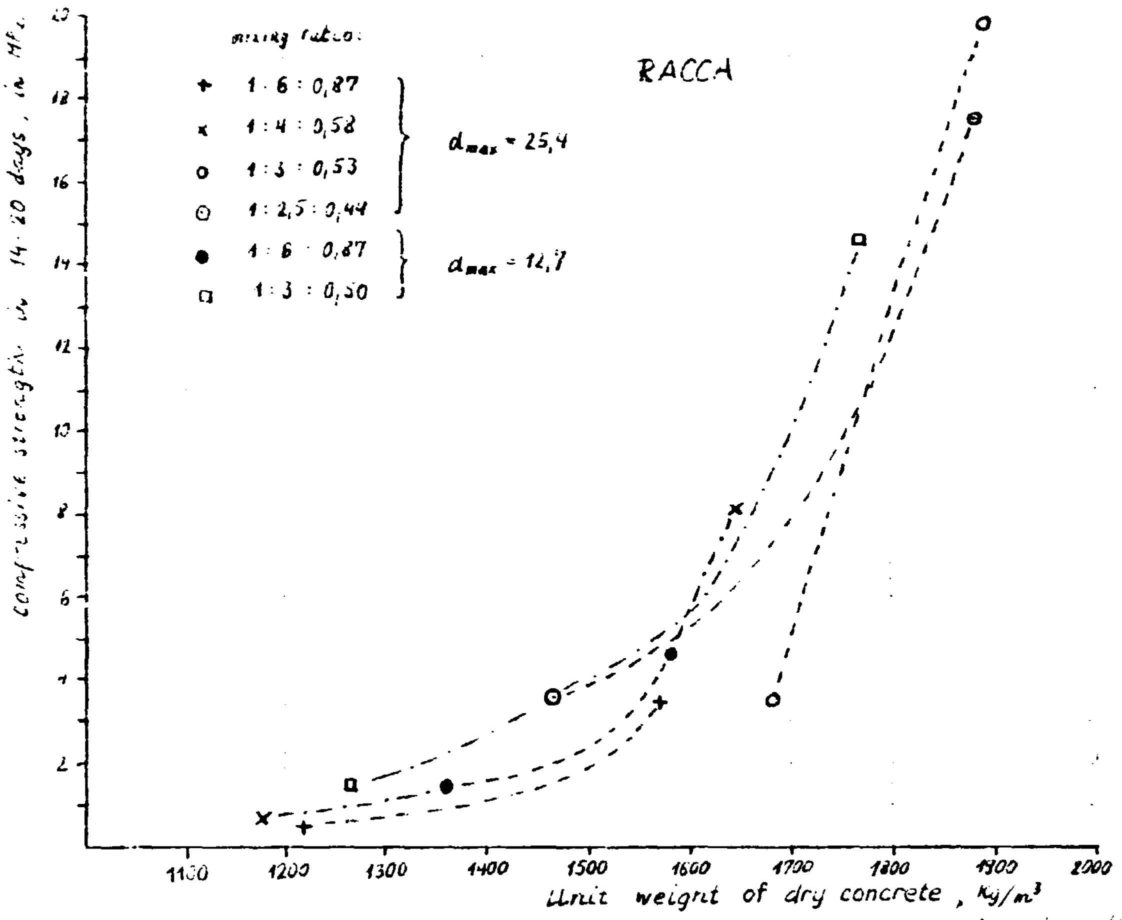


Fig. 9. Relationship between unit weight of dry concrete and compressive strength

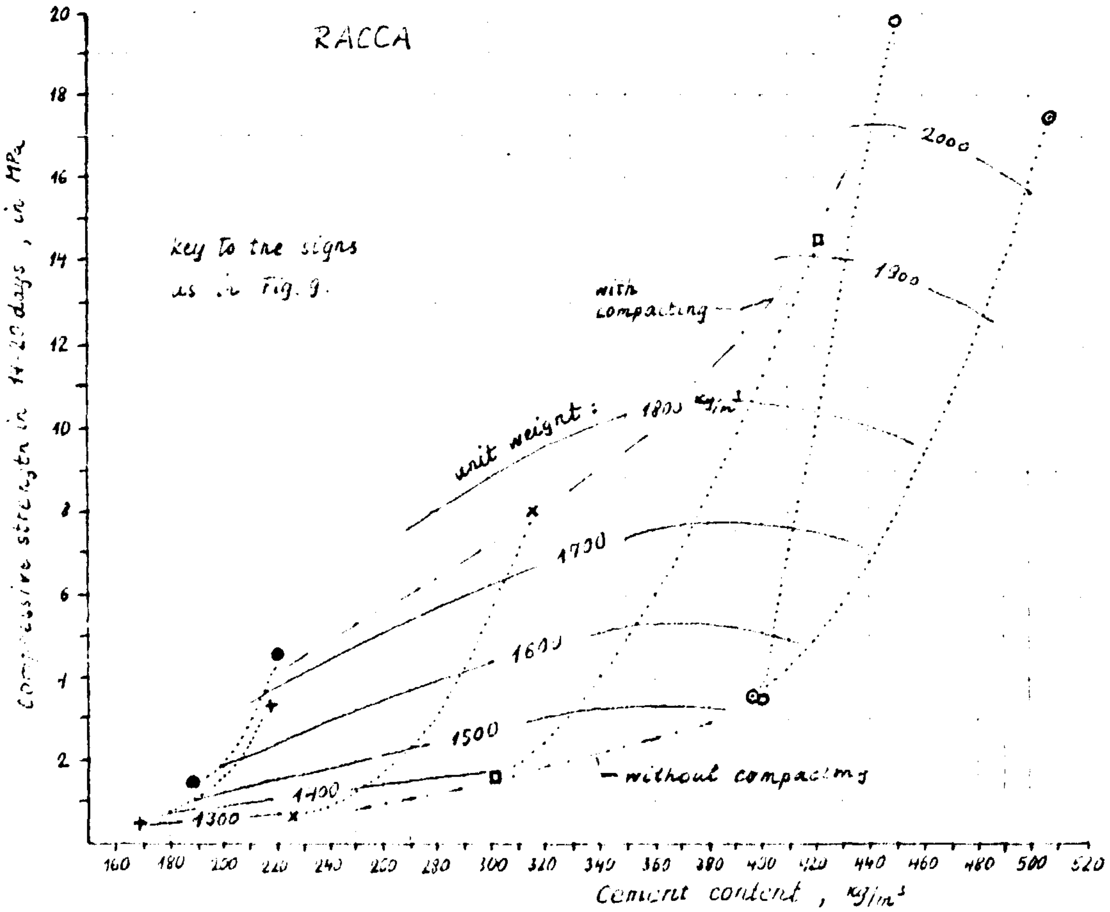


Fig. 10. Relationship between cement content and compressive strength depending on unit weight of fresh concrete and compaction.

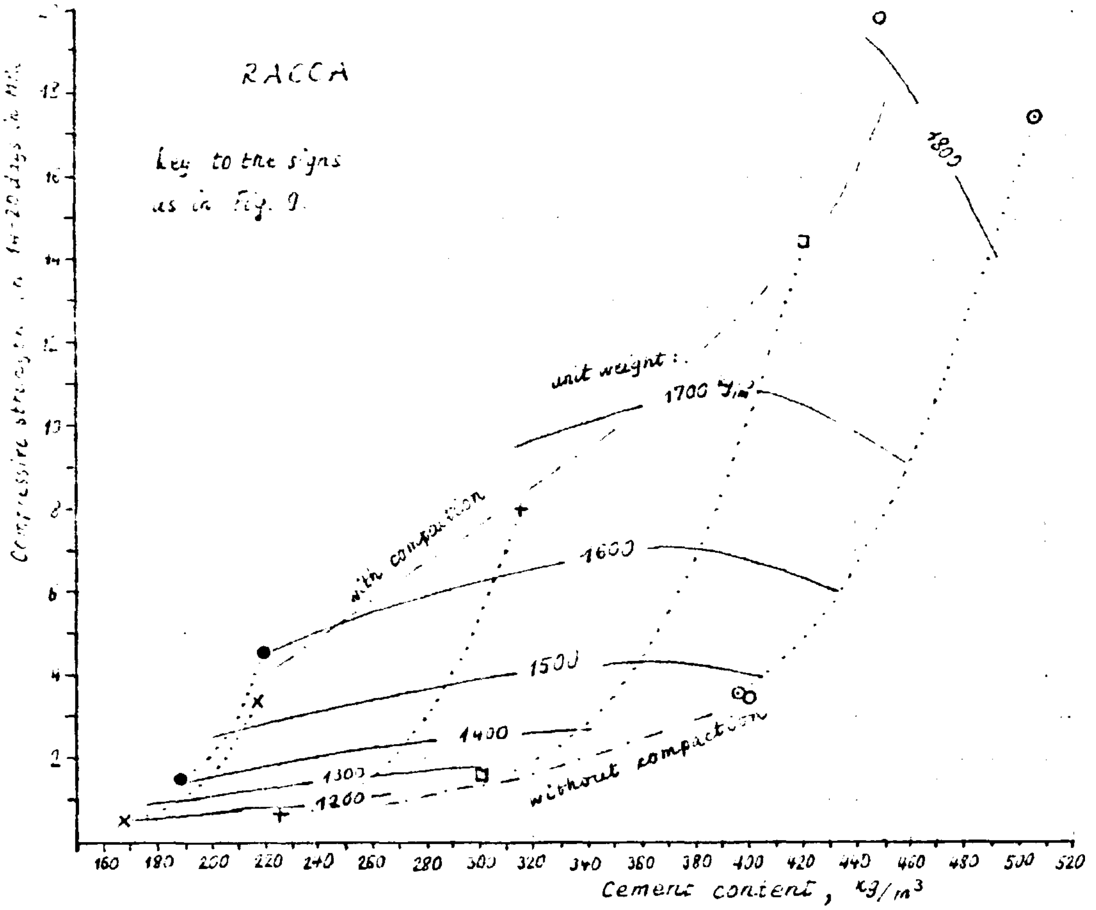


Fig. 11. Relationship between cement content and compressive strength depending on unit weight of dry concrete and compaction

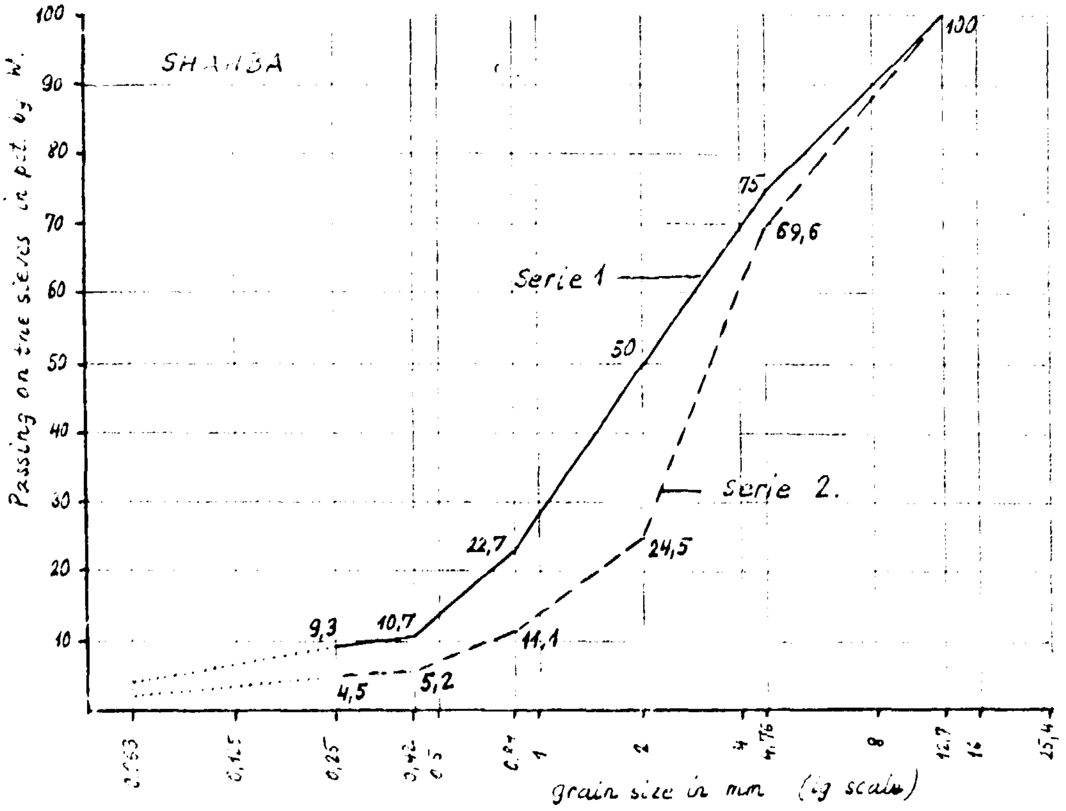


Fig. 12. Grading of aggregates made from material of Shaiba

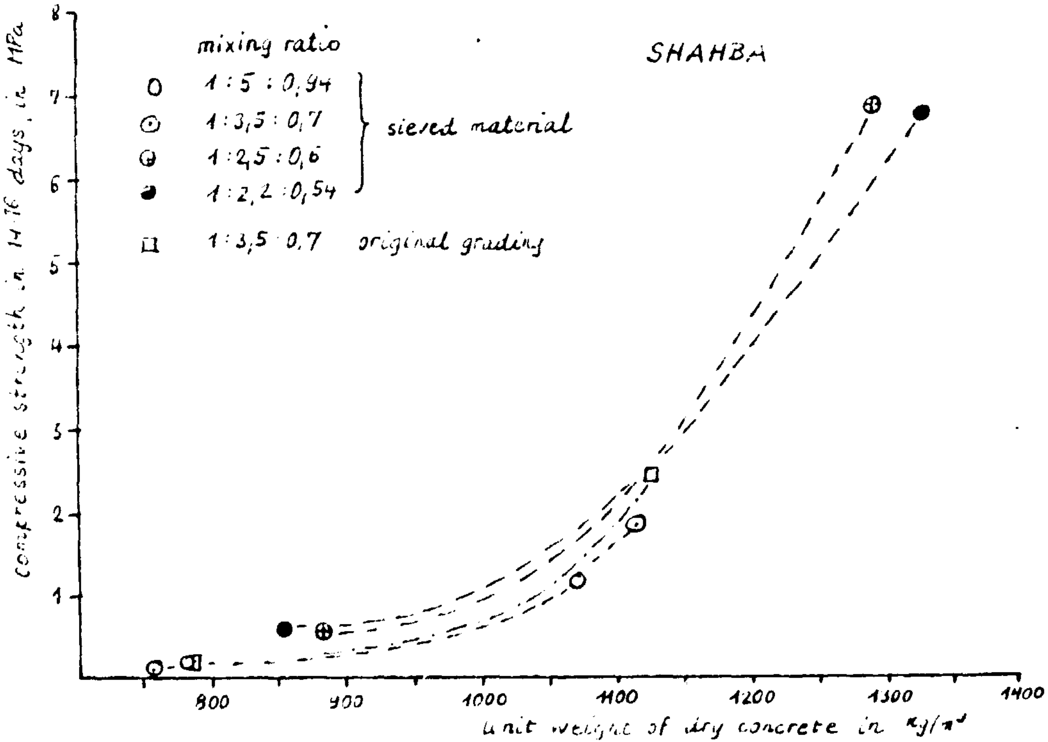


Fig 14 Relationship between unit weight of dry concrete and compressive strength

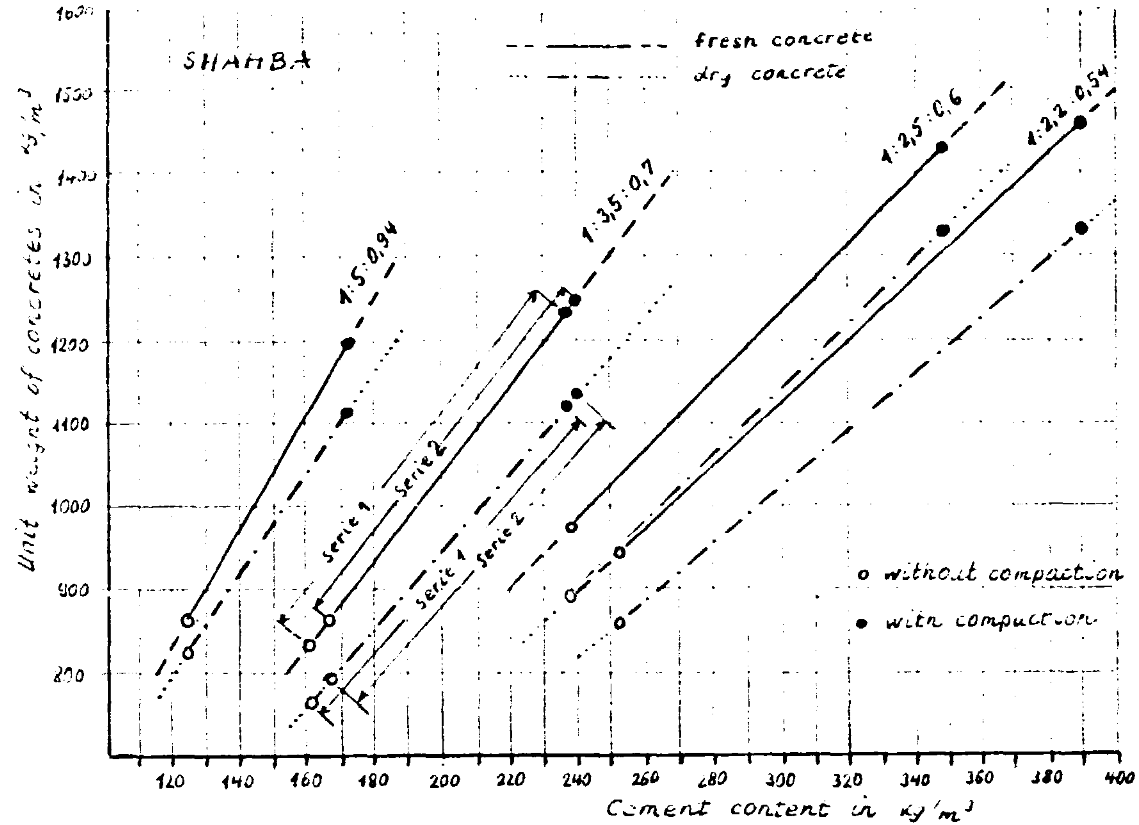


Fig. 13. Relationship between cement content and unit weight depending on mixing ratios and method of the compaction

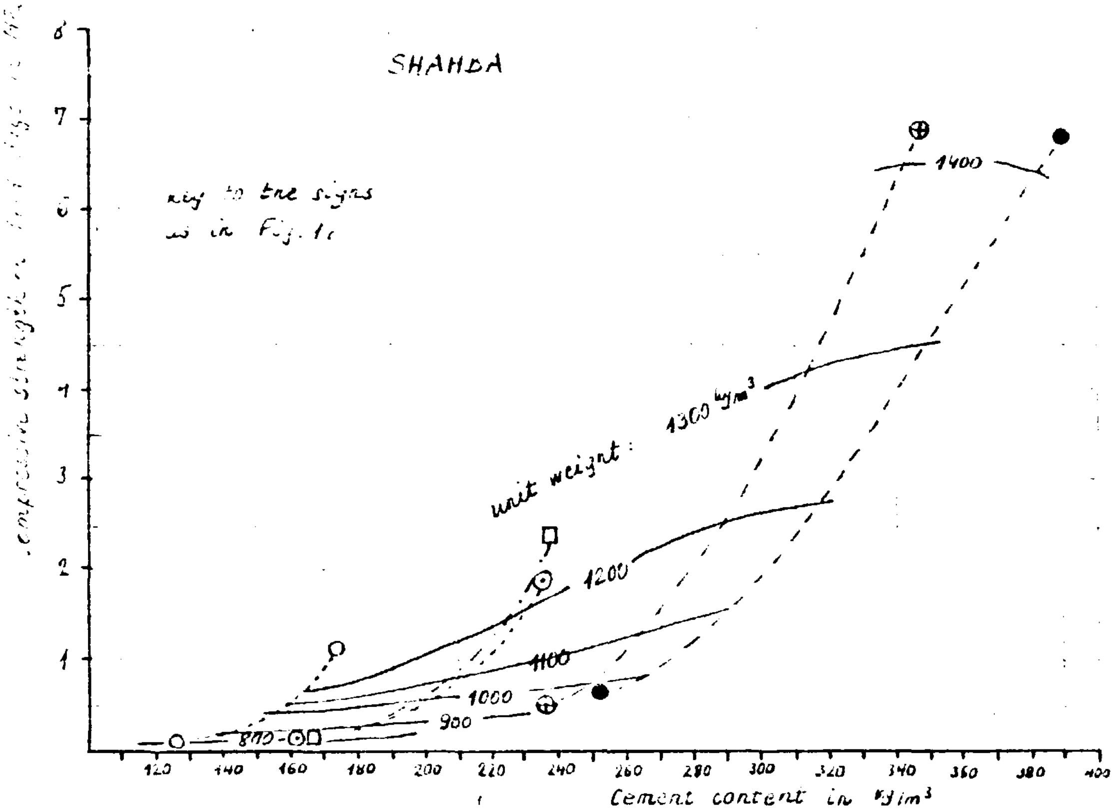


Fig. 15. Relationship between cement content and compressive strength depending on unit weight of fresh concrete and compaction

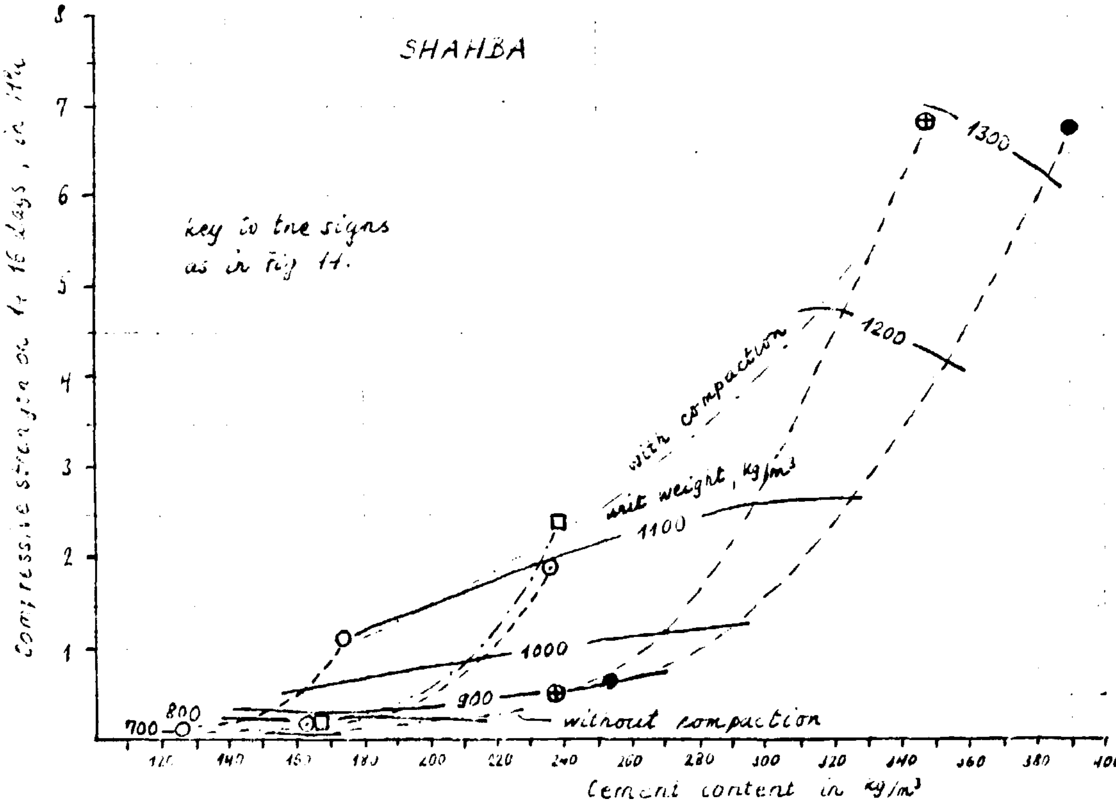


Fig. 16. Relationship between cement content and compressive strength depending on unit weight of dry concrete and compaction

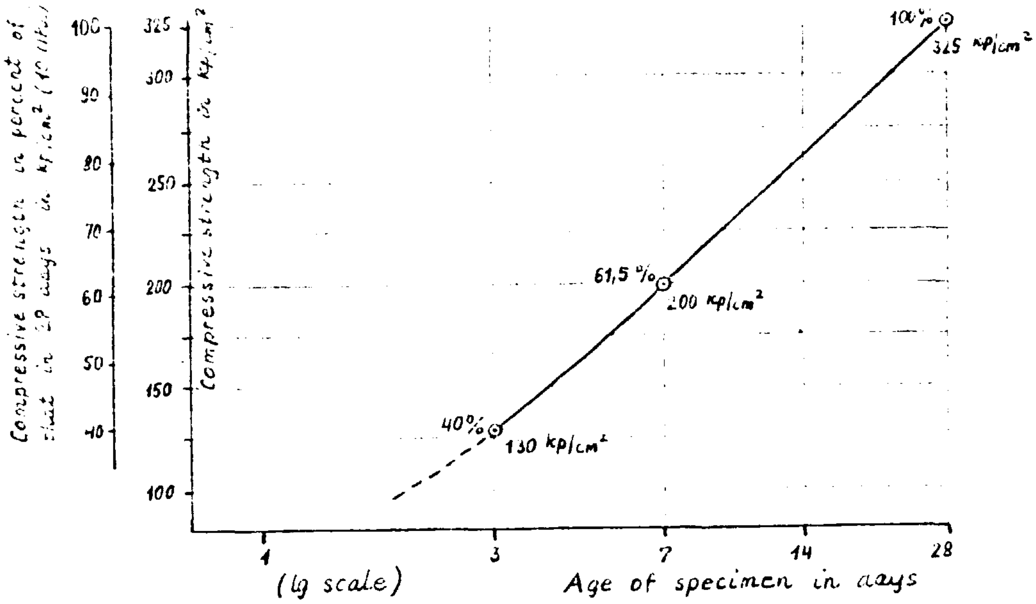


Fig. 17. Hardening process of cement used to the investigations

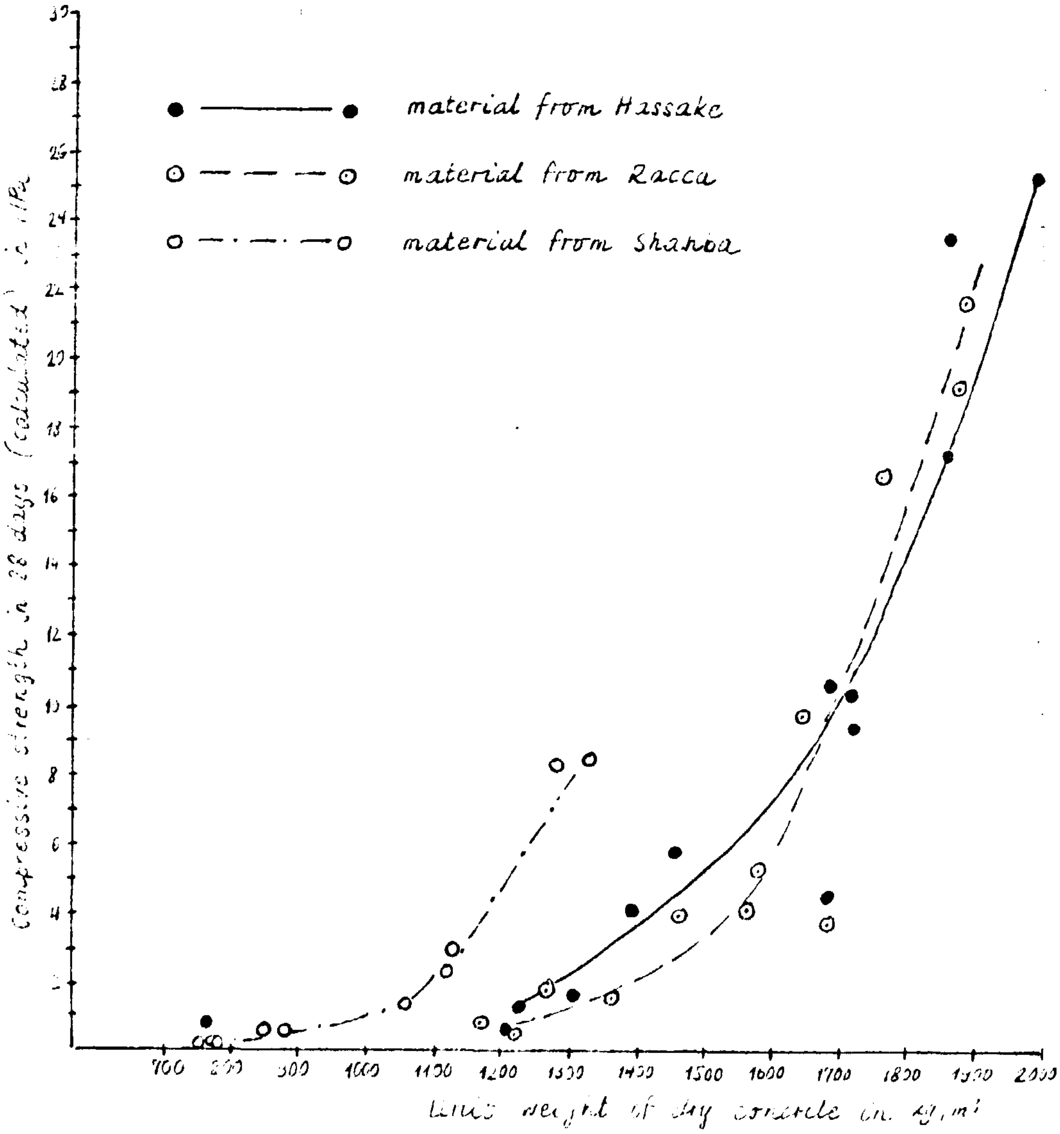


Fig. 18. Relationship between dry concrete unit weight and compressive strength in 28 days (calculated) depending on deposits

ANNEX No. 4

WHAT TO KNOW ABOUT LIGHTWEIGHT AGGREGATE CONCRETE ?

This paper was written to outlining the most important information about lightweight aggregate concretes. Its purpose is only to give basis for testing Syrian natural lightweight materials for collegues who will be working on this field in the future and will finish the research begun in September 1981 by the expert of UNIDO

1.- INTRODUCTION

The ordinary concrete has many advantages (high compressive strength, small shrinkage and creep, resistance to different environmental effects, etc) but it has also many shortages (small bending strength, heavy weight, great rigidity, bad thermal insulation, etc). To eliminate these shortages, lightweight aggregate can be used for making concrete structures.

Development of lightweight concretes has begun in this century not only because of their properties but due to deficiency of normal weight aggregates (river sand and gravel crushed stone) in many countries. e.g. in the Soviet Union and U.S.A. there are territories where normal aggregate are not available or only from great distances (more than from 1000 km) so to spare the transportation costs, utilization of local materials either natural or artificial became conspicuous.

The natural lightweight aggregates originated from volcanic activities: volcanic slags from lava flows and volcanic ashes, cinders, pumices or tuffs from eruptions. The Syrian Arab Republic has more volcanic areas where materials of good quality for concreting are available according to the previous geological and technological research work (see Annex 1, Chapter 4).

In many cases laymen think that making concrete can be easily: cement, aggregate and water should be mixed, poured into the mould, compacted and after only one duty remains: to wait until it is hardened. This mixture will probably be concrete but it will undoubtedly be uneconomic one and its quality wont satisfy the requirements.

The concrete has good quality when its properties meet the technical prescriptions and it is economic when it is made with the suitable materials and by the satisfactory technology.

The most important properties of concrete and not only that of the lightweight aggregate concrete are generally its unit weight and compressive strength. Of course, there are also other important properties but there are in close connection either with the compressive strength or with the unit weight. Such properties are the flexural or bending strength the shrinkage, the creep, the elasticity, the resistance against environmental effects, the thermal conductivity, etc.

The unit weight of concrete is generally in terms of kg/m^3 and it can be measured on different conditions: immediately after compacting (unit weight of fresh concrete), after 7, 14, 28, etc., days -(unit weight at testing) and after drying (unit weight of dry concrete). The unit weight of fresh concrete can be used for control of concrete quality. Drying is necessary since the water content of concrete depends on the humidity of the environment and the water content influences the unit weight.

The compressive strength (load-bearing capacity against pressing forces) is controlled with some kind of specimens. In one part of Standards (e.g. in the American ones) cylinders are prescribed (15 cm in diameter and 30 cm in height), other Standards require cubes (e.g. in the German ones) of length in edge of 10, 15 or 20 cm (in some cases of 30 cm). Sometimes prisms are used for testing compressive strength with dimension 4x4x16 cm (for cement mortar), 7x7x25 cm, 15x15x50 cm etc. (for concretes): first bending strength is investigated then the compressive strength on the half prisms.

It is very improtant to know about data found in the literature, what type of specimen was used for investigations, because a small cube or cylinder from the same material shows higher compressive strength than a bigger one or cylinders show lower strength than cubes. It is to be noted that the real strength of material is the same only the results of investigation change due to the different types of form. The conversion factor among the different types of specimens depends on many features (grain-size, cement-matrix, rigidity of the concrete, etc.) in general:

compressive strength in cube = 1,2 x compressive strength in cylinder

The compressive strength is usually controlled in 28 days. After concrete making, this the standard strength. If the strength was investigated earlier, the hardening process of cement used to the concrete has to be known for evaluating results. Cement 350 (according to ISO Standards) has strength in different days; in 1 day = 8-12 pct, in 7 days = 40-60 pct, in 14 days = 60-80 pct, in 28 days = 100 pct (at temperature of + 20 °C).

The process of making concrete economic and of good quality i.e. concrete of prescribed unit weight and compressive strength, is shortly as follows:

a) The most suitable materials, i.e. cement, aggregate and if it is necessary additives have to be chosen, prepared in a satisfactory way and measured their necessary quantities by weight according to the prescribed mixing ratio.

b) The weighed materials have to be put into mixer and mixed first the dry materials then added to them the weighed water continuing mixing to the necessary time.

c) After mixing the mixture has to be transported to the working place preventing it from drying, put into the mould and compacted with the suitable machine during satisfactory period of time.

d) The concrete in the mould has to be moistened in a suitable way and during required period of time.

1/--

As it can be seen in these sentences there are more attributives, suitable, satisfactory, necessary, required etc., These attributives indicate the parts where attention has to be paid to making concrete because at these parts it has to act under certain rules. By means of these rules, the density and compressive strength of concrete can be influenced and regulated.

2.- RULES OF PRODUCING LIGHTWEIGHT AGGREGATE CONCRETES

2.1 THE MOST SUITABLE MATERIALS HAVE TO BE CHOSEN

2.11 Cement

The cement is fine ground hydraulic binder, i.e. mixing with water it sets and hardens either on air or under water. The mixture of cement and water (so called: cement-paste before setting and cement-matrix after hardening) sticks the sand and gravel or other aggregates added to it and this sticked compound will be after its hardening insoluble in water.

The hardening process is the result of hydrolysis and hydration. During hydrolysis the minerals of clinker dissolve under the action of water ions, the oxides are transformed into hydroxides. The hydrolisis ends when water becomes saturated with the products of hydrolisis and with $Ca(OH)_2$.

During the hydration, different hydrosilicates and hydroaluminates come into being and temperature of concrete increases because the hydration is exotherm process.

To this hardening process, water and temperature above 0°C are needed. When the concrete dries up during setting of cement, the hydrolysis stops, and concrete looses its strength.

When the temperature decreases below 0°C, the water in solution freezes and hardening process will be suspended.

5/ ..

When the environmental temperature is too high (above +30°C), the hardening process becomes faster, the temperature of concrete increases fastly, the concrete dries up easily.
To make concrete in hot climate, cements of slow setting are advisable.
The strength of concrete depends on the strength of cement: the stronger the cement is, the higher strength the concrete has. Standards of different countries prescribed different methods for testing cement quality, therefore the trade-names of cements of the same quality could be different. Recently the testing method of cement has been unified by ISO (International Standard Organization) and trade names of cement became uniform (signes: 250, 350, 450 and 550 which figures represent the compressive strength of standard cement mortar in 28 days in terms of kp/cm^2). With cements of different strengths can be produced ordinary concretes of strengths according to Table 1 (made with quartz sand and gravel).
In the Syrian Arab Republic cements of 350 are generally available.

2.12. Aggregate

Aggregate is used to concrete for sparing cement and improving concrete properties. The properties of aggregates influence both unit weight and compressive strength of concrete.
Unit weight is influenced by the weight of aggregate (first and for most by the bulk density, see Annex 2, Chapter 2). The lighter the aggregate is, the lighter concrete can be produced. Some data can be seen in Table 2.
Compressive strength of concrete is determined mainly by the crustiness and grading of aggregate. The strength of the aggregate influences also the concrete strength but its effect is of less importance.

E.g. compressive strength of 40-50 MPa can be reached both with expanded clay and quarz aggregates although the strength of expanded clay grains is only about tenth part of that of quarz gravels.

Investigation methods of aggregate strength are described in Annex 2, Chapter 2. The results of this investigations are characteristic also for crustiness of aggregate grains. These properties of natural aggregates (strength and crustiness) are given, therefore grading is the only feature which can be modified or rather improved.

The grading means the proortion of different grain sizes; what quantity can be found in aggregate from grains of 0-0.1mm, 0.1-02mm, 0.2-0.5mm etc. This grain distribution of aggregate can be illustrated by grading curves (examples are shown in Annex 3). The forms of grading curves can be seen in Fig. 1.

The form of aggregate grading influences the properties of fresh and hardened lightweight concrete as follows:

a) If the grading is similar to the curve of Fig. 1.A (little quantity of fine grains), the workability of concrete mixture is generally insufficient, therefore both unit weight and compressive strength vary in lower range.
Usually such grading is used to the "no fines concrete" which is utilized to cast-concrete for wall constructions made in site.

b) If the grading is similar to the curve of Fig. 1.B -(bigger quantity of fine grains), the workability of concrete improves, therefore both unit weight and compressive strength increases. Usually such grading is used to load bearing constructions made with lightweight aggregate concretes.

c) If the grading is similar to the curve of Fig. 1.C (gap grading), the density of concrete increases though the workability does not improve, since the mixture is inclined to seggregation.

7/...

In some cases, utilization of such grading cannot be avoided, e.g. when lightweight aggregate can only be produced in coarser grains (expanded clay) and for producing cement mortar in enough quantity supplement of natural sand is needed.

d) If the grading is similar to the curve of Fig. 1.D (irregular curve), the properties and design of concrete become uncertain.

The correct grading depends on the given properties of lightweight aggregate and the required properties of concrete therefore to determine it exactly, research work is needed.

Usually gradings according to Fig. 2 are used to the investigations. With every grading the same mixing ratio should be utilized (e.g. 1:4:0.8). Water content can be determined according to water absorption of aggregate (in the example water absorption is 20 pct by weight, i.e. to aggregate of 4 part by weight, water of 0.8 part by weight can be added).

The mixture should be compacted by the same method (e.g. on vibrating table) and compressive strength should be tested in 28 days. On the basis of results, the suitable grading of aggregate can be determined. Usually, compressive strength of concrete made with aggregate of 10 pct from 0-1mm is the lowest. Increasing content of 0-1mm grains results at the beginning increasing in compressive strength, after reaching the optimum the compressive strength decreases.

The optimum content of 0-1mm grains depends also on the mixing ratio. The tendency can be seen in Fig. 3 The goal of investigation of aggregate grading to establish the real data of relationship shown in Fig. 3, which is the basis of the further research work (see later).

8/...

2.13 Admixtures

The properties of concrete can be influenced by admixtures. Concrete admixtures are special chemicals added to the batch before or during mixing. The quantities used are, with few exceptions, very small, neverthless they can impact certain desirable properties to the concrete that cannot be secured by other methods or not as economically.

The most frequently used admixtures are:

a) accelarators to increase the rate of setting or the rate of hardening or both at early ages, including some of the soluble chlorides (primarily calcium chloride), carbonates and silicates

b) water reducing and set retarding admixtures to reduce the water requirement of concrete, or to retard the set, or both, including lignosulfonic acids, hydroxylated carboxylic acids, carbohydrates, polyols, and the salts and modifications of these (primarily calcium lignosulfonate)

c) air-entraining admixtures to introduce a system of small air bubbles into the fresh concrete during mixing, usually anionic surface-active agents

d) finely divided mineral admixtures to increase the chemical resistance of concrete, reduce the heat of hydration, reduce expansion produced by alkali-aggregate reaction, improve the properties of fresh concrete, and so on, including natural and artificial pozzolans (primarily fly ash), hydraulic lime, blast furnace slag, and ground quartz.

It is important to recognize that admixtures are no substitute for sound concrete-making practices. As a matter of fact, the proper utilization of admixtures requires increased care, for instance, in batching. The other aspects of the concrete-making procedure should also be kept as constant as feasible.

Since many admixtures affect more than one property of concrete, sometimes affecting desirable properties adversely, and since these effects may be dependent on several factors (brand and type of cement, etc) and since the mechanism of action of most admixtures is not quite clear, in using any admixture, careful attention should be given to the instructions provided by the manufacturer of the product. Also, an admixture should be employed only after appropriate evaluation of its effects, if necessary by use of trial mixes with the particular concrete.

The most important additive for lightweight aggregate concrete is the air-entrainer. This chemical improves the workability, i.e. the mobility, the cohesivily, the water-retention and compactibility of the fresh concrete as well as it can substitute the very fine aggregate particles (below 0.2mm). The air-entrainers bring into beings very fine air-bubbles is not as high as 5 pct by volume, the compressive strength of the hardened concrete is improved too.
The air content, size distribution of air voids in an air-entrained concrete and the compressive strength are influenced by many factors, among the more improtant of which are :

a) the nature and concentration of air-entraining admixture (for information see Fig. 4)
b) the nature and proportions of the ingredients of the concrete (for information see Fig. 5)
c) the type and duration of mixing employed (for information see Fig. 6)
d) the consistency
e) temperature and other factors influencing the setting time
f) kind and degree of compaction applied in consolidating the concrete.

10/...

Before the utilization of air-entrainer to making lightweight aggregate concrete, experiments are needed to clear the above effects. It is advisable to use for these investigations aggregate grading determined by testing according to Fig. 2 or 3 and mixer, which will be used for producing concrete in situ.

2.2. THE BASIC MATERIALS SHOULD BE PREPARED IN A SATISFACTORY WAY

No trouble exists with preparation of the cement and admixtures, since they are prepared in and transported from the factories. The cement should in the working place be protected from every kind of humidity. Namely the cement begins to set when it is touched by water or by humidity of air and it can be utilized nevermore.

The preparation of lightweight aggregate means crushing and screening. There are some aggregates - perlite, certain types of scoria or pumice, expanded clay, etc. - which do not require crushing and screening, they are utilizable in their original state. If the original material is granulous, the fine grains (0-1mm) are, however, not to be found in it, it must not be crushed for getting powder, but other fine grains (e.g. limestone sand) should be employed. This is the case for material of Shahba.

For choice of the suitable crusher to the lightweight aggregate, it has to be known that frequency distribution (probability curve) of the grains of crushed material is generally logarithmic-normal i.e. it is inclined to the left and shifted - more or less - towards the axis of ordinate (see Fig.7A).

But it is true for materials crushed by equipments in which many crushing effects hit the grains (mills and fine grinding machines such as hammers) only. When the material is crushed by any other type of crushers, grain size distribution of materials will be - although somehow regular - but different from the Fig. 7.A. Rocks crushed by conic or jaw crushers have a Gauss-type frequency distribution (see Fig. 7.B), while rollers (working at a low crushing rate) give rise to right shifted frequency distribution. The latter is demonstrated by Fig. 7.C.

As a practical conclusion of the above rules it can be stated, that

a)hammers and giratory crushers are to be preferred when at least 40 pct by weight of fine material(0-1mm) is needed

b)about 30 pct by weight of fine material can be produced by crushing on jaw or conic crushers

c)high percentage of coarse material can be reached by using rollers and the quantity of fine material remains to be little.

For choice of crusher, on the one hand the above rules should be taken in account and the results of investigations according to Figures 2 and 3 on the other.

2.3. THE NECESSARY QUANTITIES OF MATERIALS HAVE TO BE WEIGHED

The most important two requirements for lightweight aggregate concrete are the relatively low unit weight and the relatively high strength, but these two properties contradict each other.

There is namely existing a general relationship between unit weight and compressive strength as it can be seen in Fig. 8. According to this Figure, the highest the unit weight is, the higher the compressive strength.

In this general relationship, however, many special relationships are included. Some examples:

- the relationship between unit weight and compressive strength depending on cement content is shown in Fig. 9
- the relationship between unit weight and compressive strength depending on aggregate grading (in terms of 0-1mm grain content in pct of aggregate weight) is shown in Fig. 10
- the relationship between unit weight and compressive strength depending on water content is shown in Fig. 11

Such special relationships can also be determined for other features, e.g. for type and quantity of admixtures, for mixing time and method, for compacting methods, etc

Primarily the relationship between cement content and unit weight depending on ~~unit weight~~ mixing ratio should be determined by method described in Annex 2 (Chapter 3 and Figures 4 and 5). To this investigation grading of medium fine content is advisable (about 30 pct by weight). The method includes also the investigation of compacting effect.

For determining the suitable mixture, it should be taken in account that lightweight concrete must be produced with unit weight less than or equal to the prescribed one and with compressive strength higher than or equal to the requirement. E.g. if the prescribed quality is in compressive strength 10MPa and in unit weight 1500 kg/m^3, the real quality must be:

in compressive strength	Rc	10MPa
in dry unit weight	Sd	1500 kg/m^3

The composition of concrete can be calculated as follows:

- cement content (m_c in kg/m^3) can be determined on the basis of relationship according to Fig. 5 in Annex 2.
- water chemically bound by cement can be assumed:
  $m_{wb} = 0.2\ m_c$ in kg/m^3
- aggregate content (m_a in kg/m^3) from the rpescribed dry unit weight (Sd): $m_a = Sd - (m_c + 0.2\ m_c) = Sd - 1.2 m_c$
  Unit Weight of fresh concrete (Sp) can be calculated from the aggregate water absorption (w_a in part by weight):
  $Sf = m_a + m_c + m_a \cdot w_a$

13/...

E x a m p l e

Requirement in compressive strength is : Rc = 15 MPa
Requirement in dry unit weight is: : Sd = 1600 kg/m^3
Water absorption of aggregate in 0.5 hour (according to previous investigation) comes to 15 pct, i.e. Wa = 0.15
Demand in cement content for fulfilling the requirement of Rc = 15MPa compressive strength (according to the previous investigations) comes to : $^m c$ = 300 kg/m^3
Aggregate content should be: $^m a$ = 1600 - 1.2.300 = 1240 kg/m^3
Unit weight of fresh concrete is:
Sf = 1240 + 300 + 1240. 0,15 = 1726 kg/m^3 ≈ 1730 kg/m^3
Mixing ratio (cement:aggregate:water) =

$$\frac{300}{300} : \frac{1240}{300} : \frac{186}{300} = 1 : 4,13 : 0,62$$

It should be mentioned that the quantity of concrete ingredients can be expressed in two ways as it can be seen above: in terms of kg/m^3 (concrete composition) and in terms of part by weight (mixing ratio).

From the same mixing ratio many concrete compositions can derive which depend on the compacting effect, i.e. on the unit weight of fresh concrete. E.g. the mixing ratio is as above:
1: 4,13: 0,62 and the unit weights of concretes made with this mixing ratio but compacted differently: 1200, 1400 and 1600 kg/m^3.
The concrete compositions are as follows:

Unit Weight in kg/m^3	Cement	Aggregate	Water
	content in kg/m^3		
1200	208.7	861.9	129.4
1400	243.5	1005.6	150.9
1600	278.3	1149.2	172.5

Calculation of concrete composition from the mixing ratio and the unit weight of fresh concrete is as follows:

Amount of parts in weight has to be calculated and the unit weight of fresh concrete has to be divided with this amount. With the quotient, each part (by weight) has to be multiplied. E.g. calculation of concrete composition from above data for unit weight of 1400 kg/m^3:

Amount of parts	:	1+4,13+0,62 = 5,75
Quotient	:	1400: 5,75 = 243,5
Cement content	:	1. 243,5 = 243,5 kg/m^3
Aggregate content	:	4,13. 243,5 = 1005,6 kg/m^3
Water content	:	0,62. 243,5 = 150,9 kg/m^3

For information, compositions of lightweight concrete made with different aggregate are shown in Table 3. (from the Hungarian Code Practice).

2.4 INGREDIENTS OF CONCRETE HAVE TO BE MIXED IN SUITABLE WAY

Mixing is used to transform the granulous materials into homogeneous mixture. Heap of dry materials (aggregate and cement) consists of different grains and air between grains i.e. it can be considered as a preliminary compaction. With mixing it can be obtained that the water would cover grain surfaces of aggregate and cement, hereby it decreases internal frictions and gives the necessary humidity to setting and hardening cement.

The mixing is effective if

- its carrying out is needed relatively short time
- ingrediants of concrete are moving on forced course
- finishing the mixing, only a few air remains between the grains
- ingrediants (cement and aggregate grains, water and perhaps admixtures) are divided homogeneously in the mixture

The necessary mixing time is determined by type of mixer therefore it is advisable to determine by trial mixing. At this investigation not only the average compressive strength but also the standard deviation should be controlled.

Some results of such investigation (carried out in Hungary) can be seen in Fig. 11.

According to these results, mixing of very short time yields very high standard deviation: it comes in controlled mixer to 35 pct, but in free fall mixer to 60 pct at mixing time of 10 s. At this short time, a low compressive stength can be obtained only. At increased mixing time, the results become better but in free fall mixer it has to be taken care of the too long mixing time too.

Fig. 11 shows relationship for one conrete composition (cement content of about 200 kg/m^3, medium fine grains (0-1mm) content. If the composition changes so does the standard deviation and average compressive strength too. E.g. if the quantity of fine grains decreases, the standard deviation will increase because of decreasing the fresh concrete cohesivity.

It has to be mentioned that the load-bearing capacity of constructions depends both on average compressive strength of their material and standard deviation of compressive strength. It can be supposed that the compressive strength has generally Gauss-type frequency distribution according to Fig. 12. (normal distribution). If the standard deviation of compressive strength is signed by S (in MPa) and the average compressive strength is signed $\overline{Rc}$ (in MPa), the values belonging to the different probability levels are;

probability level 5% $R_{fc} = Rc - 1,645. S$

probability level 2,3% $R_{fc} = Rc - 2.S$

probability level 0,4% $R_{fc} = Rc - 3,4\ S$

according to the Gauss-function.

R_{fc} (so called treshold value of the compressive strength) means the permissible lowest strength, below which determined percent of the real strengths can occur (e.g. lower strength than $R_{fc} = Rc - 1,645.S$ can occur with probability of 5 pct.).

The up to date calculation of load-bearing capacity of the constructions is based on probability principles (in general the treshold value belonging to the probability level of 5 pct is accepted).

16/...

therefore knowledge of the standard deviation of compressive strength is indispensable, Its necessity can easily be comprehended by an example:

Two concrete series have the same average compressive strength: R_{c1} and R_{c2} = 20 MPa. Compressive strength of one of them fluctuates between 15 and 25 MPa, that of the other fluctuates between 10 and 30 MPa. Standard deviation of one of them comes to S_1 = 1,5 MPa, that of the other comes to S_2 = 2,9 MPa. It is obvious that the first concrete has higher load bearing capacity than the second one because the first has more uniform quality. The treshold values of the compressive strength (at the probability level of 5 pct) are:

$$R_{fc1} = R_{c1} - 1{,}645 \cdot S_1 = 20 - 1{,}645 \cdot 1{,}5 = 17{,}5 \text{ MPa}$$
$$R_{fc2} = R_{c2} - 1{,}645 \cdot S_2 = 20 - 1{,}645 \cdot 2{,}9 = 15{,}2 \text{ MPa}$$

Mixing of lightweight aggregate concrete is very similar to that of the ordinary concrete. The literature suggests the pre-saturating of the lightweight aggregate. Its reason is, that though water absorption of lightweight aggregates is generally quick, it continues, however, more minutes.
If dry aggregate is put into the mixer and then the water, the water absorption begins but it does not finish in the mixer. In this case the concrete can lose slowly its workability and by the time when its compaction is begun, the concrete is already so dry that it cannot be converted into dense.

The pre-saturated aggregate contains the necessary quantity of water, therefore it is not needed to add more water in the mixer.

The pre-saturation of volcanic lightweight aggregate is, however, in general not necessary.

2.5 THE CONCRETE HAS TO BE COMPACTED WITH SUITABLE MACHINE DURING SATISFACTORY TIME

The importance of compaction could be seen in Annex 2., in Figures 4 and 5.

From the point of view of compaction, the workability is the most important property of the fresh concrete.

The workability can be investigated with many different methods which can be divided into following groups:

a) investigation of fresh concrete deformation (Abrams-method)

b) investigation of fresh concrete's readiness for compacting (RILEM - Glanville method)

c) investigation of penetration degree of some heavy, solid body into the fresh concrete (Graf-method)

d) investigation of transformation degree of the fresh concrete (Powers - method)

The description of these methods can be found in technical literature. Here only one method will be discussed: investigation procedure of fresh concrete's readiness for compacting.

After mixing, from fresh concrete samples should be taken out and measured its bulk density. For the investigation the moulds (cubes or cylinders) can be used in which the concrete specimens will be made. The fresh concrete should poured into the mould loosely and the upper part of the concrete should be smoothed without compacting. The loose concrete in the mould should be weighed and the bulk density of the concrete should be calculated (S_{cb}, in kg/m^3).

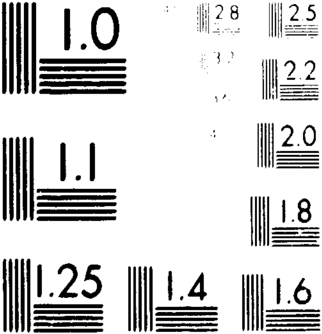
Then specimens from the same concrete mixture will be made with the given compacting machine and after smoothing, their unit weight will be calculated (S_f in kg/m^3)

The readiness for compacting (in pct):

$$C_r = \frac{S_f - S_{cb}}{S_{cb}} \cdot 100$$

Concrete readiness for compacting expresses, that - after the given compacting - with how many percentages the fresh concrete will be heavier than without compacting.

The above outlined method is similar to the RILEM-Glanville's one but the RILEM-Glanville method uses a compacting machine to obtain a maximum density (i.e. theoretically ideal compacting machine really), the outlined method uses practical compacting machine, which is generally used in situ. Nevertheless, if one concrete has good workability for one type of compacting machines, it does not indicate, that the same concrete has also good workability when other type of compacting machine is used.



MICROCOPY RESOLUTION TEST CHART

This is why the here outlined method is prefered to the RILEM-Glanville one.

During compacting, the air-bubbles are expelled from the cement paste of concrete, the aggregate particles are going to come close to each other, the concrete density and its compressive strength increase. If compacting time is short, the above written process is interrupted, concrete does not obtain the prescribed strength. If compacting time is long, it can be observed two faults. One of them is the flowing out the cement paste, the other is the too high unit weight of concrete. As it was mentioned in Chapter 2.3, the required water content was given from result of aggregate water absorption. It should be completed here taking into consideration the compacting process.

Concrete readiness for compacting depends on grading of aggregate (primarily on its fine content), on the quantity both of cement and water. Easy to realize: the easier is compacting granulouse materials, the lower is the frictional force among the particles. Together with the fine grains (cement and aggregate below 1 mm) the water gives possibility to decrease the friction. The higher is the water content, the lower the frictional force is i.e. the less compacting effect (capacity and time) is needed. It can be seen in Fig. 13;: when in the same cement: aggregate mixture the water quantity is increasing, by unchanged compacting effect the density is also increasing till the optimum point, but using more water leads to decreasing in density.

The relationship between water content and compressive strength can be seen in Fig. 14 for different aggregates by using the same compaction. For the sake of comparability, in the Fig. 14 the ordinary concrete can also be found. From this Fig. can be stated how the water content influences the unit weight and compressive strength of different lightweight aggregate concretes.

2.6 **THE COMPACTED CONCRETE SHOULD BE CURED SATISFACTORILY**

To setting and hardening cement water is required. In the first setting period, the water added at mixing is satisfying, but when the water has evaporated, setting and hardening process of the cement would be interrupted. Therefore it has to be hindered drying by keeping the wet conditions by watering.

Its length of time depends on the air humidity, sunshine, wind etc. The prescriptions require in general curing of minimum 7 days.

Making concrete specimens in laboratory and investigating their compression strength, curing is also required. It has to be known that the water content or humidity of concretes influences their strength in two ways:

a) some types of aggregates (principally materials with raw clay content) are smoother in wet than in dry state; therefore concretes made with these aggregates are weaker in wet than dry conditions

b) testing results of concrete specimens depend on surface humidity of concrete, because friction comes into being between the pressing plate and the concrete surface. The lower the tested compressive strength is even if the real compressive strength is the same.

Therefore it should be taken care of equal humidity of specimens by keeping curing conditions equal.

Curing of lightweight aggregate concrete is generally: 1 day (maximum 2 days depending on strength) in moulds under wet clothes or in fog chamber (air humidity greater than or equal to 96 pct), after taking out from the moulds they are put in water. Two four days before testing, the specimens are taken out from the water and stored at dry conditions (maximum 65pct. air humidity) up to testing.

3.- INVESTIGATION PROGRAM OF SYRIAN LIGHTWEIGHT VOLCANIC MATERIALS

Intention of information in Chapter 2.1 - 2.6 was to establish to make evident the program of investigations of Syrian light weight volcanic materials presumably suitable for making concretes. It seemed to be necessary to summarize the most important information because the expert of UNIDO stays in Syria only to the end of October so the finishing the investigations and evaluating their results are charge of Syrian counterpart.

3.1 PURPOSE OF INVESTIGATION

The purpose of these investigations to compare the properties of lightweight volcanic materials that can be found in many parts of Syria for selection and on the basis of results to choose the most suitable materials for building industry.

The previous estimations established that these materials should be primarily considered for producing concrete so the investigations shall be concrete technological ones. During these investigations should be determined the using fields of materials (for load-bearing constructions, for masonry-units, for thermal insulating products) as well as the main parameters of technology to be employed to production.

3.2 METHODS OF INVESTIGATIONS

The methods employed to investigations of aggregate should be based upon RILEM recommandations (Réunion Internationale des Laboratoires sur les Essais des Matèriaux et des Constructions, Paris). The methods employed to investigations of concrete technology can be recommanded to base upon system developed by author (see in Annex 2).

At this time there is no suitable laboratory in Syria for carrying out the investigations. The laboratory of Ministry of Communication has only a few moulds, there is no crusher screener and mixer and the storage place for specimens is close (for about 30 specimens only).

-1/...

In the Industrial Testing, Research and Development Centre there is not concrete laboratory. Mr. A. Bozanovic, expert of UNIDO, has suggested in his Report (Terminal Report on Assistance to Development of Building Materials, SI/SYR/76/801, Damascus, 20 Oct. 1978) to build up laboratory of concrete technology and so has did Mr. Z. Prijic, expert of UNIDO in his final report (DP/SYR/77/004/11-17/F/3 ... Damascus December 1980).

Direction of Research Centre wants to equip this laboratory in the near future to which Report of Mr. Bozanovic contains recommendations detailed. The investigations can start after having equiped this concrete laboratory. Author suggests to carry out the investigations in the Research Centre in close co-operation with the General Organization for Cement and Building Materials. The instruments, which will be available in this new laboratory for testing, can modify the practical performance of investigations but without any modifications of their theoretical basis.

3.21 COMPARATIVE TESTING OF DEPOSITS

For comparative testing, samples should be taken out from different deposits of volcanic material. In Annex 3, material of three deposits (Hassake, Racca and Shahba) can be found. According to the information, Syria has more volcanic deposits (e.g. near Adra) and in one deposit, more types of material can be found.

It can be suggested to carry out investigations of every type of material as follows:

a) testing bulk density of materials on grain sizes of 0-1, 1-4, 4-8 and 8-16 mm (according to ISO sieves)
b) testing strength of material particles on grain size of 8-16 mm or 4-8 mm
c) testing crushability of materials by jaw crusher in laboratory scale (with investigation of grading of the crushed material)
d) testing water absorption
e) testing unit weight and specific gravity of the rock.

Results of testing bulk density shall be plotted against results of testing self strength (strength of particles). In Fig. 15 the sketch of this relationship can be seen. This Fig. gives the basis of evaluation, because it is advisable to choose materials of low density and simultaneously of high compressive strength for detailed investigations. Of course for choice of materials for detailed investigations, the estimated volume of deposit and the transportation distances and possibilities should be taken into consideration.

According to this evaluation samples of big quantity (at least 5 m^3) should be taken out from suitable deposits for testing concrete technology and properties of concrete.

3.22 TECHNOLOGICAL INVESTIGATIONS

The technological investigations should be carried out with big samples (at least of about 5 m^3). The object of these investigations is to determine the technological behaviours of the material, the method of producing concrete and the properties of concretes.

a) Preparatory Work

The raw material arrives for the investigations in rock slumps - apart from a few exceptions - therefore the material has to be crushed. The choice of the crusher to the big samples depends on the result of previous investigation of crushability (see 3.21.C). Three results are possible:

a) the ground material had fine grain (0-1 mm) content of about 30 pct; in this case, jaw crusher should be used for grinding the big sample.
b) the ground material had fine grain content less than 30 pct; in this case, hammer or giratory crusher should be used for grinding the big sample
c) the ground material had fine grain content more than 30 pct; in this case, roller should be used for grinding the big sample.

(cp. Fig. 7). After crushing, the material should be screened on the sieve of 16 mm.

The properties of the crushed material from the big sample should be investigated according to Chapter 3.21

) General Investigation

As a result of the preparatory work, aggregate is available with maximum grain size of 16 mm and fine content of about 30 pct. With this aggregate, concrete mixtures shall be made for getting the relationships shown in Annex 2. (Figures 4 and 5).

The mixing ratios depend on the bulk density of the aggregate heap. Such mixtures are required to make from which concretes with cement contents of 100, 200, 300 and 400 kg/m³ can be produced without compaction. For information:

- if the bulk density of aggregate (measured on 0-16mm heap) comes to about 1000 kg/m³, the proposed mixing ratios (cement: aggregate) are:

  1:10, 1:5, 1:3.3 and 1:2.5
- if the bulk density of aggregate (measured on 0-16mm heap) comes to about 600 kg/m³ the proposed mixing ratios (cement:aggregate) are:

  1:6, 1:3, 1:2 and 1:1,5

While the cement content of concrete made without compaction is less than or equal to 300 kg/m³, the mixing water can be equal to the water absorption of the aggregate. When cement content becomes more than 300 kg/m³, the water content can be increased by 15 pct of cement excess. E.g. water absorption of aggregate is 20 pct, composition of concrete is:

1200 kg/m³ of aggregate, 400 kg/m³ of cement. The mixing water w = 1200.0,2 + (400-300).0,15=240+15=255 kg/m³.

In this case the mixing ratio is: 1:3:0,6375

The quantities of ingredients (cement, aggregate and water) to one mixture can be calculated from the mixing ratio, the volume and the expectable unit weight of concrete specimens.

E.g. if 12 cubes of 20x20x20 cm will be made from one mixture, the mixing ratio is 1:3:0,6375 and the expectable unit weight of concrete is 1600 kg/m^3, the quantities of ingredients are as follows:

- volume of 12 cubes : 12.8 = 96 dm^3
- weight of 12 cubes : 0,096.1600 = 153,6kg
  which will be raised to make a round figure and taken in account the losses = 170 kg
- sum of parts : 1+3+0,6375 = 4,6375
- cement quantity : 170:4,6375 = 36,66 kg
- aggregate quantity : 36,66.3 = 109,97 kg
- water quantity : 36,66.0,6375 = 23,37 kg

The calculated quantities of the materials should be weighed and mixed in controlled mixer during 90 s. First cement and dry aggregate are mixed during 30 s then water is added to and mixing is continued further 60 s.

From each mixture, 4x3 specimens shall be made. The first three specimens will be made without compacting: the mixture will be poured into the mould and cleared down its top with metal ruler without compacting too. The unit weight of specimens (i.e. the bulk density of fresh concrete) will be measured.

The second three specimens will be made with the strongest compacting which can be applied altogether. After compacting the top surface will be smoothed and the unit weight will be measured.

Between these two unit weights (lowest and highest) two intermediate unit weights shall be chosen. The appropriate concrete quantity will be weighed and compacted into the mould (appropriate quantity means the quantity which is in accordance with unit weight and mould volume).

The compressive strength of specimens will be investigated in 28 days. In possession of results, the relationships according to 4 and 5 Figures in Annex 2 can be drawn.

e) Detailed Technological Investigations

In the course of detailed technological investigations the effect of following factors should be tested:

I effect of aggregate fine content

II effect of water content

III effect of air entrainer admixture

I Effect of aggregate fine content

General information can be seen in Fig. 16, where date of research carried out by author (in Hungarian Institute for Building Sciences, Budapest) are shown (aggregate: blast furnace slag; crumbling factor of Hummel: 0,83; bulk density of aggregate: 760 kg/m^3).

The effect of aggregate fine content can be investigated with different concrete compositions and with the same compacting method (highest compacting effect)

The following grading can be suggested:

Fractions in mm		0-1	1-4	4-16
Parts in pct	IA	10	30	60
	IB	20	30	50
	IC	35	30	35
	ID	50	30	20

The mixing ratios depend on the bulk density of aggregate heap (according to Chapter 3.22 b). Such mixtures are required to make, from which concretes with cement contents of 150, 225, 300, 400 and 500 kg/m^3 can be produced with the highest compacting effect. On the basis of results, the relationship according to Fig. 16 can be plotted.

II Effect of Water Content

General information can be seen in Fig. 14. The effect of water content can be investigated with two concrete composition.

The compacting method should be conform to the concrete workability, since the workability improves with increasing water content.

If the water quantity is very small (the concrete workability is bad), the concrete has to be compacted very strongly (e.g. long time vibrating under pressure), but concrete of very high water content can only be compacted by a short time vibration (by longer time vibration, one part of cement paste would be leaking from the concrete).

Such mixtures can be proposed to make, from which concretes with cement contents of 200 and 400 kg/m^3 can be produced with the medium water content. This medium water content should be conform to that which was used at investigations according to Chapter 3.22 b. The water content can be changed with 2-5 pct in relation to aggregate weight.

In the following example, real data are shown from investigations of author (aggregate: rhyolit tuff). The data of the investigations can be seen in Table 4. The relationship is plotted in Fig. 17.

From Fig. 17, it can be stated that increasing water content improves the concrete workability and in consequence of this fact, the compressive strength of the concrete increases at the same unit weight of dry concrete. Therefore is advisable to add rather more water than less.

III Effect of Air-Entrainer Admixture

The air entrainer admixture improves the workability of concrete (see Chapter 2.13, consequently the investigation of effect of this additive should be concerned testing the readiness of compacting. Mixtures of different composition should be made without and with admixture and after having measured their bulk densities, they should be compacted with high effect.

The air entrainer makes decreasing water quantity possible without change of the original workability (i.e. workability of concrete made without admixture), therefore the permissible degree of water decreasing and its effect on compressive strength should be investigated.

The air entrainer can replace the very fine aggregate particles (below 0.2 mm), therefore the effect of the decreasing fine content can be investigated on concretes made without and with admixture.

27/...

3.23 Further Investigations

On the data obtained from the comparative testing of deposits and the technological investigations, concretes produced with each type of aggregate can be classified in the appropriate group according to Annex 2., Chapter 1 (thermal insulating concrete, load bearing and thermal insulating concrete, load bearing concrete). This classifying can be performed by taking in account the obtainable upper and under limits of unit weight and compressive strength, together with the technical and economic possibilities, i.e. cement content should not be higher than about 450 kg/m^3 and the compacting effect should not be very low.
On the basis of under and upper limits it can be established the category the given concrete can be included in.
The category will specify the further investigations to be carried out. These investigations can be found in Table 5.
The testing methods are regularized by Standard so they will not be discussed here. Number of specimens shall fulfill terms of Standards.

a) Bending Strength

Concretes of following compressive strength are advisable to be made for investigation of bending strength (compressive strength in MPa):

Thermal insulating concretes	0.5	1,	3.5	-,	-	-	-	-	-
Intermediate concretes	-	-	-	5	10	15	-	-	-
Load bearing concretes	-	-	-	-	-	-	20	25	30

The bending strength depends primarily on the mortar matrix (cement + fine aggregate content) of concrete and the compacting effect. Therefore, on the basis of previous investigations, the mixing ratio, the fine aggregate content and the air entrainer admixture should be chosen for vigorous compaction.
The results of bending strength investigation can be plotted against the compressive strength, according to Fig. 18. It should be mentioned that the bending strength of lightweight aggregate concrete is generally higher than that of ordinary concrete for the same compressive strength.

b)Young-modulus (modulus of elasticity)

Young modulus is the directional tangent of curve origin drawn for relationship between deformation and stress. Testing Young modulus, the specimen is loaded with a relatively small force (e.g. 500 kp) and origin curve concerns to this point (see Fig. 19).

Young modulus of ordinary concrete depends only on its compressive strength. Different Standards give formulas for relationship between compressive strength and Young modulus (E.), e.g. formula of Roš:

$$E_0 = 600\,000 \frac{Rc}{Rc+150}$$

Where R_c = compressive strength investigated on the same prism as the deformation, in kp/cm^2

Young modulus of lightweight concretes depends both on compressive strength and unit weight. Schäfler worked out the following formula: $E_0 = 6000 \sqrt{S \quad R_c'}$

where S = unit weight of concrete in kg/m^3

R_c = compressive strength investigated on cube, in kp/cm^2

It must be called attention: the multiplying factor (6000) cannot be constant, it depends on the type of aggregate , furthermore other authors (e.g. Paw) does not give linear relation for unit weight but he calculates with $S^{2/3}$.

To investigate Young modulus, specimens (prisms) of about following compressive strength shall be made:

intermediate concrete	5	10	15	-	-	-
load bearing concrete	-	-	-	20	25	30

Since Young modulus is to be investigated in prism, the compressive strength should also be investigated on prisms and Young modulus shall be measured at stress level of 30 pct prism's compressive strength.

C)Shrinkage

Drying concrete yields shrinkage and absorbing water does swelling. If concrete has a great shrinkage, it is inclining to cracking. Shrinkage can be tested on concretes according to Chapter 3.23 a

Change of shrinkage depending on time should be drawn according to Fig. 20.
The shrinkage of concrete is a reversible process, therefore quick testing for information can be carried out with the following method:
The concrete specimens (generally prisms) are placed under water. After saturation its length will be measured with a precision measuring instrument (required accuracy is 1/100 mm). Then the specimens are put into drier (temperature of drier + 30°C) and after having dried, its length is measured. Length after saturation is Ls, that after drying is Ld and the shrinkage is

$$Sh = \frac{Ls\ (in\ mm) - Ld\ (in\ mm)}{Ls\ (in\ m)}\ mm/m$$

d) Freezing-Thawing Resistance

This concrete property is determined by testing decrease of compressing strength of of dynamic Young modulus in consequence of frost action.
The test method is an accelerated one; the concrete specimens are exposed to frost during (after their water saturation) during ... hours, then they are put under water of temperature of + 15 or + 20 °C for some hours. This process will be repeated many times (10 or 25 or more).
Freezing thawing resistance shall be tested on concretes according to Chapter 3.23 b.
The best method is the investigation of decrease of dynamic modulus of elasticity under the influence of freezing thawing process, because on the basis of results it can be drawn the change of decrease depending on the time, according to Fig. 21.

e) Thermal Conductivity

Thermal conductivity (λ) is quantity of heat expressed in Joule which passes in steady heat condition through layer perpendicular to the current of heat conduction, during 1 s. Thickness of the layer is 1m and its surface is $1m^2$

The difference of temperatures of two layers' surface (inner and outer) should be 1K. The thermal conductivity is in terms of W/m.K (since J/s = W).

For testing thermal conductivity many methods are known (e.g. instrument of Poensgen, that of Bock or of Nusselt etc). The type of specimens (form and size) is determined by the instrument used.

The following concretes can be suggested for the investigations. Thermal insulating concrete with unit weight of 600, 800, 1000 kg/m^3. Intermediate concretes with unit weights of 1000, 1200, 1400, 1600 kg/m^3.

The thermal conductivity is influenced not only by the unit weight, but also by the type of fine aggregate used. Therefore, when lightweight concretes of the same unit weight are made partly with natural sand, partly with light weight sand, their thermal conductivity should separatly be investigated.

f) Water Absorption

Water absorption can be investigated on any kind of specimen (cube, cylinder, prism, plate, etc). The specimens should be dried at temperature of + 105°C then saturated with water.

To expell air bubbles from the concrete, it is advisable to put specimens only in a few water (the height of water level should be 2 cm at the beginning of investigation) and after every one hour, the water level shall be raised with 2cm. The quantity of absorbed water should be often measured and the investigation will be continued until no difference can be determined between two consecutive measurements.

g) Speed of Drying

The concrete specimens saturated with water should be placed in well defined climate (e.g. air humidity = 65%, temperature = +20°C).

31/...

The specimens should be weighed in every day and the investigation will be continued until no difference can be determined between two consecutive measurements.
The results of investigation shall be drawn according to Fig. 22;

3.24 Complementary investigations

Properties of lightweight aggregate concretes are influenced by more factors. To investigate effect of certain factors is needed for getting satisfactory knowledge about every technological requirement. In the course of complementary investigations it is necessary to determine:

a)effect of type of sand on unit weight and compressive strength
b)effect of type of sand on bending strength
c)effect of type of sand on Young modulus
d)effect of cement content on bending strength
e)effect of compacting method on bending strength
f)effect of cement content on shrinkage
g)effect of content and type of sand on shrinkage
h)effect of air entrainer on freezing-thawing resistance
i)effect of air entrainer on water absorption
j)effect of air entrainer on speed of drying
k)effect of steam wuring on compressive strength
l)the setting and hardening process of lightweight aggregate concretes.

3.25Unforseeable Difficulties of Conrete Research Work

Concrete properties are influenced by a number of known and probably more unknown factors. Great part of known factors can be found in the previous Chapters. One could almost say that during investigations every single one of these influencing factors can be followed with attention but only by maximum careful and accuracy. It is not at all unlikely that, despite of the greatest possible care during the investigations faults are creeping into the results.

Therefore, every possible relation must immediately be drawn (or sketched) for evaluating data, e.g. after measuring bulk density of fresh concrete, the relationship between cement content and density or that between water content and density shall be sketched.
Furthermore, every circumstances should be put down e.g. temperature of laboratory room etc.
For the sake of collection of every fact, information, data etc., bound minute book should be used which is to be kept as a diary. The minute book should be paginated before the beginning of investigations. Any page must not be torn out from this book.
If any result were found contradictory to the known or the hypothetical (presumed) relationship, the investigation must be repeated.
Author would like to make evident by the above that concrete research work - as every research work - does not go straight does not walk on the beaten track, but it clambers up narrow, untrodden paths and on this way the special knowledge is the single compass.

3.3 NUMBER OF SPECIMENS

The following specimens with one type of aggregate should be made:

General investigations (Chapter 3.22b): 4 mixing ratios x 4 compacting effects x 3 specimens	=48 specimens
Effect of aggregate fine content (Chapter 3.22 C.I.): 4 fine contents x 5 cement contents x 3 specimens	=60 specimens
Effect of water content (Chapter 3.22.C.II) 2 cement contents x 6 water contents x 3 specimens	=36 specimens
Effect of air entrainer admixture (Chapter 3 22 c.III): 2 cement contents x 3 admixture contents x 2 water contents x 2 fine aggregate contents x 3 specimens	=72 specimens
Amount of technological investigation (Chapter 3.22)	= 216 specimens

Further investigations (Chapter 3.23):

Bending Strength (Chapter 3.23a): 3 concrete types x 3 specimens	= 9 specimens
Young modulus (Chapter 3.23 b) : 3 concrete types x 3 specimens	= 9 specimens
Shrinkage (Chapter 3.23.c): as bending strength	= 9 specimens
Freezing thawing resistance (Chapter 3.23d): as Young modulus	= 9 specimens
Thermal conductivity (Chapter 3.23.e): 4 concrete types x 3 specimens	= 12 specimens
Water absorption (Chapter 3.23f): as bending strenght	= 9 specimens
Speed of drying (Chapter 3.23.G): the specimens of water absorption testing can be used	
Amount of further investigations (Chapter 3.23.)	= 57 specimens

Complementary investigations (Chapter 3.24)

a)2 mixing ratios x 4 natural sand content x 3 specimens	= 24 specimens
b)3 concrete types x 2 sand contents x 3 specimens	= 18 specimens
c)3 concrete types x 2 sand contents x 3 specimens	= 18 specimens
d)4 mixing ratios x 3 specimens	= 12 specimens
e)4 compacint methods x 2 sand conte x 3 specimensç	= 24 specimens
f)4 mixing ratios x 3 specimens	= 12 specimens
g)2 mixing ratios x 2 sand contents x 3 specimens	= 12 specimens
h)3 concrete types x 3 specimens	= 9 specimens
i)3 concrete types x 3 specimens	= 9 specimens
j)the above specimens (i) can be used	
k)4 concrete types x 4 curing methods x 3 specimens	= 48 specimens
l)3 concrete types x 6 moments (e.g. 3,7,14,28,90 and 180 days) x3 specimens	= 54 specimens
Amount of complementary investigations (Chapter 3.24)	=240 specimens

34/...

Type of specimens:

- for investigation of compressive strength, water absorption ∅ 15x30cm cylinders = 378 specimens
- for investigation of bending strength Young modulus, shrinkage 10x10x40 cm prisms = 123 specimens
- for investigation of thermal conductivity, e.g. 25x25x7 cm plates = 12 specimens

Amount of specimens = 513 specimens

Volume of concrete to be made:

in cylinders	378 x 0,0053	= 2,0 m^3
in prisms	123 x 0,004	= 0,5 m^3
in plates	12 x 0,0013	= 0,02 m^3
	Amount	2,52 m^3

Volume of volcanic material from one type, taking in account the compacting factor and the losses comes to about 4 m^3 It can be seen that many specimens are to be made. But it must be taken into consideration that in the above program the minimum research work is given, therefore the number of specimens must not be decreased.

The investigations should be carried out in one rate; one transport of cement (about 1,2 tons), one transport of aggregate (about 4 m^3) should be used and production of specimens should be finished in limited time with the same collaborators. The results can be evaluated only in this way.

Table 1.: Compressive strength of concretes made with different cements and consistencies

Type of cement	Consistency of concrete		
	semi-plastic	plastic	fluid
250	25 - 30	17 - 22	10 - 15
350	40 - 45	27 - 32	15 - 20
450	50 - 55	36 - 41	20 - 25
550	60 - 65	43 - 48	25 - 30

in terms of MPa

Table 2.: Unit weight of concretes (in kg/m^3) made with different aggregates

Type of aggregate	Bulk density of aggregate in kg/m^3	Unit weight of concrete in kg/m^3	Field of utilization
steel balls	5000 - 6000	3000 - 4500	radiation protection
Quarz sand and gravel	1600 - 2000	2000 - 2500	load-bearing constructions
heavier volcanic tuff	900 - 1100	1600 - 2000	
expanded clay	600 - 800	1200 - 1800	
lighter volcanic materials	500 - 800	1000 - 1800	wall constructions
Expanded perlite	50 - 400	250 - 600	thermal insulation

Bulk density is tested on 4-12 mm grains

Table 3.: Compositions of some concretes made with lightweight aggregate (data from Hungarian Code Practice)

Aggregate	Compressive strength R_c in MPa	Unit weight of fresh concrete in kg/m^3	Unit weight of dry concrete in kg/m^3	Cement content in kg/m^3	0-1 mm aggregate content in kg/m^3	1-16 mm aggregate content in kg/m^3	Water content in kg/m^3
Expanded clay	10	1445	1350	260	400	625	160
	14	1500	1400	290	400	640	170
	20	1610	1500	320	400	710	180
	28	1720	1600	360	450	720	190
	40	1850	1700	400	500	730	200
Volcanic tuff	10	1675	1400	270	270	800	335
	14	1800	1500	310	300	830	360
	20	1920	1600	340	350	845	385
	28	2075	1720	390	440	845	400

Table 4. Data of investigation for water content effect

Mixing ratio cement : : aggregate : : water	Water content in pct of aggregate	Unit weight	Cement content	Water content	Unit weight of dry concrete in kg/m³	Compressive strength in MPa
		of fresh concrete in kg/m³				
1 : 5 : 1,20	20	1540	214	256	1327	1,5
1 : 5 : 1,45	25	1600	215	311	1332	5,6
1 : 5 : 1,60	28	1620	214	341	1322	8,3
1 : 5 : 1,70	30	1630	211	359	1313	9,8
1 : 5 : 1,80	32	1640	210	378	1304	10,8
1 : 5 : 1,95	35	1650	206	403	1288	11,0
1 : 5 : 2,20	40	1650	201	443	1247	9,0
1 : 3 : 0,80	20	1610	335	269	1408	3,5
1 : 3 : 0,95	25	1680	340	323	1425	11,4
1 : 3 : 1,04	28	1730	342	356	1442	16,6
1 : 3 : 1,10	30	1760	349	383	1447	18,0
1 : 3 : 1,16	32	1780	345	400	1443	19,0
1 : 3 : 1,25	35	1800	344	429	1440	19,5
1 : 3 : 1,40	40	1800	334	467	1400	18,2

Table 5. Work schedule of the further investigations

Designation of concrete	Bending strength	Young modulus	Shrinkage	Freezing-thawing resistance	Thermal conductivity	Water absorption	Speed of drying
Thermal insulating concrete	+		+		+	+	+
Intermediate concrete	+	+	+	+	+	+	+
Load-bearing concrete	+	+	+	+		+	+

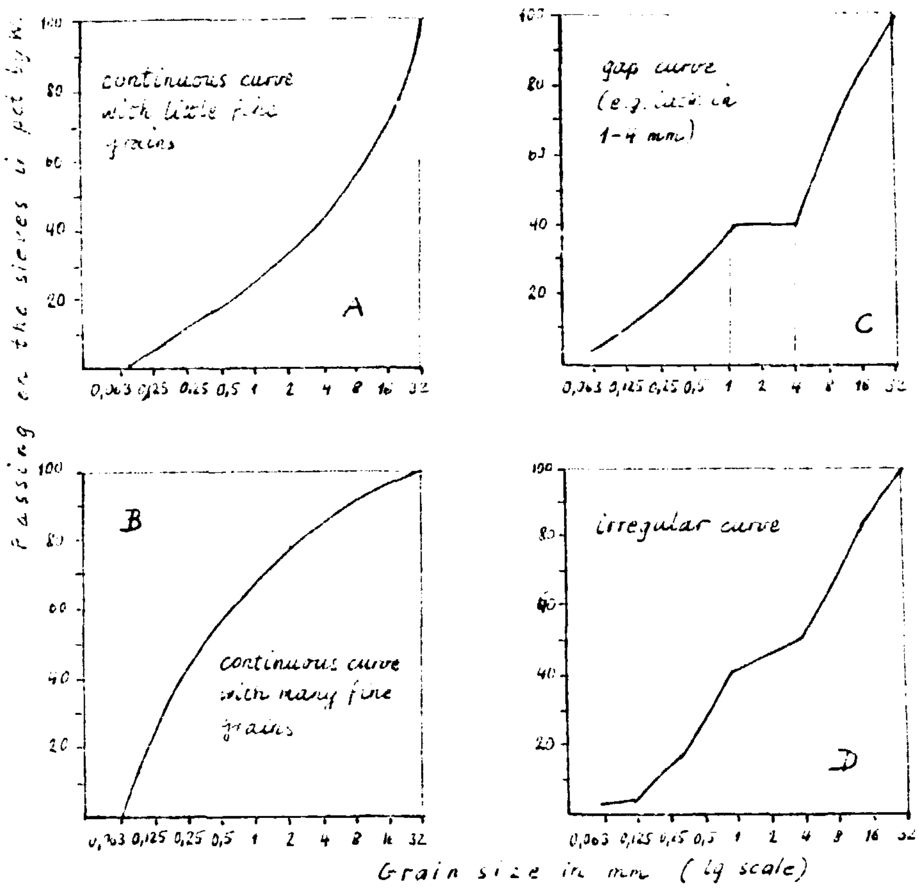


Figure 1. Forms of aggregate grading curves

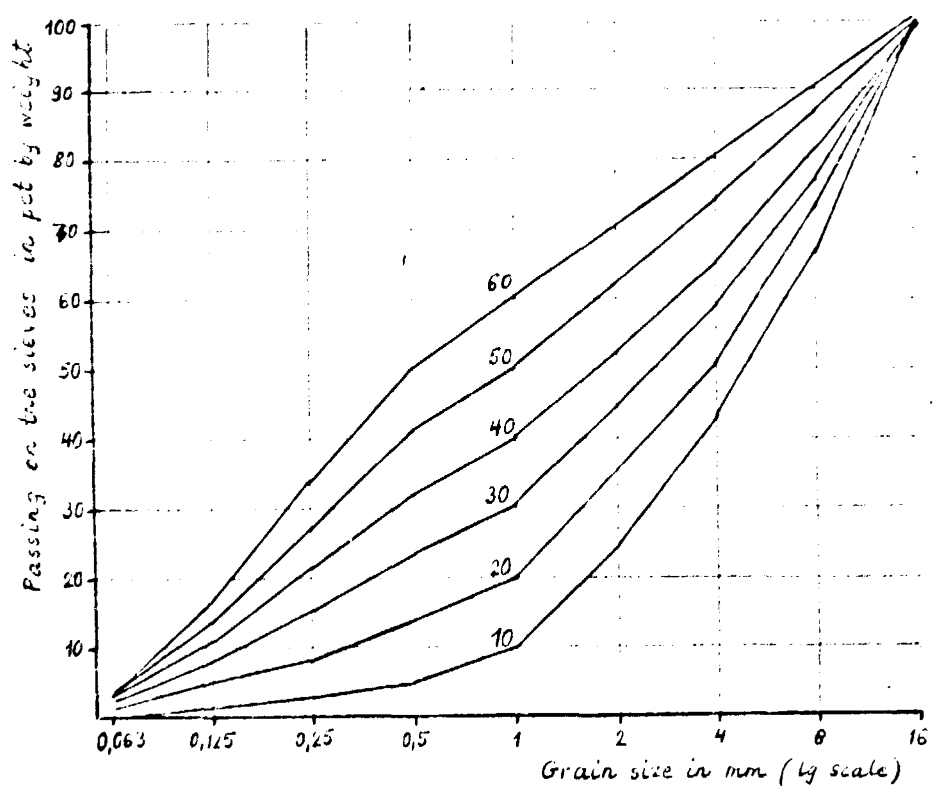


Figure 2. Gradings for lightweight aggregate investigation

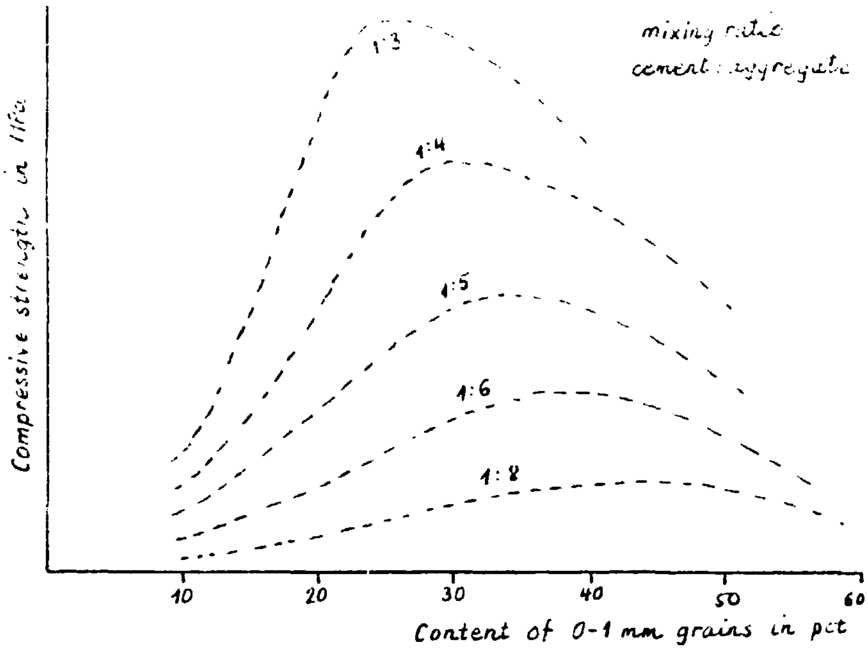


Fig. 3. Tendency of relationship between 0-1 mm grain content and compressive strength depending on mixing ratio

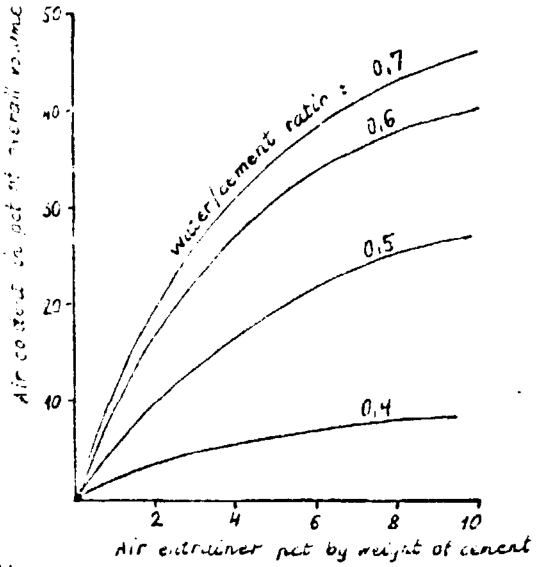


Fig. 4. Air-entrainment in cement paste as influenced by water-cement ratio and dosage of air-entrainer

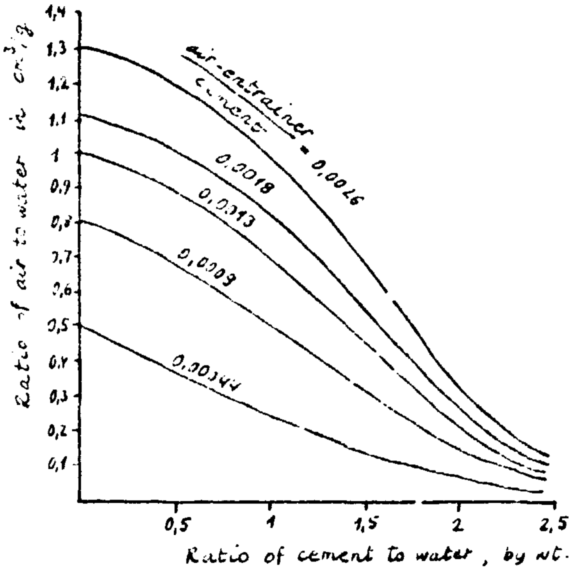


Fig. 5. Effect of air-entrainer content on air entrainment in mixtures of cement and water (mixing in high-speed stirrer)

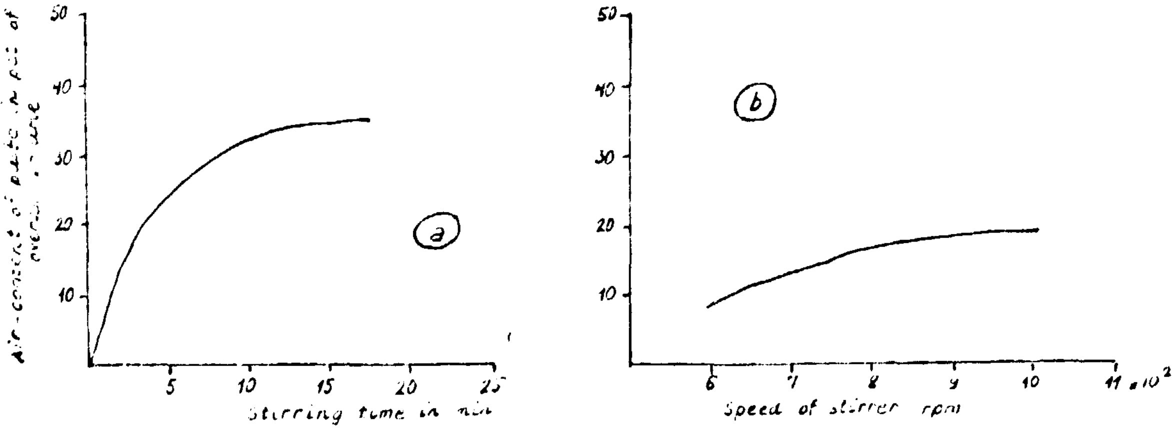


Fig. 6. Effects of stirring time and speed of the stirrer on the air content of neat paste. a) The speed of the stirrer was 1000 rpm b) The stirring time was 3 min.

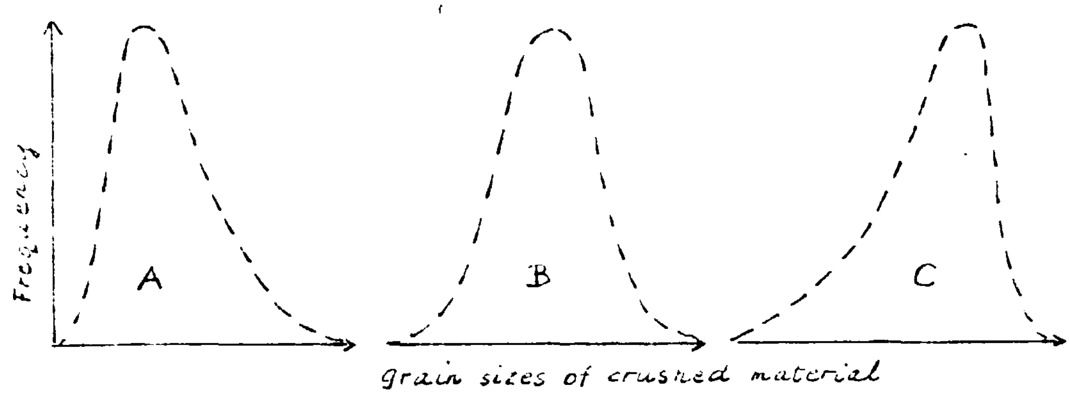


Fig. 7. Frequency distribution of grain sizes of material crushed by different equipments

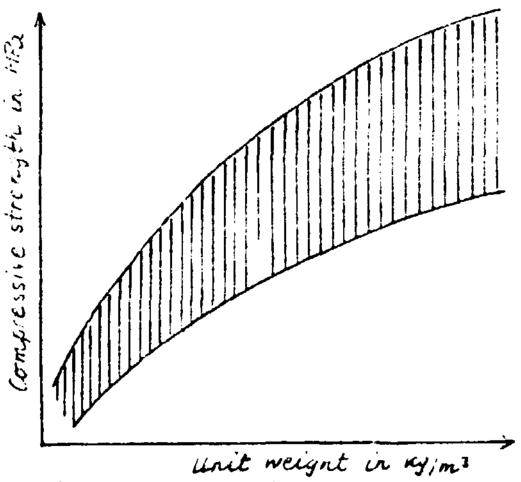


Fig. 8. General relationship between unit weight and compressive strength

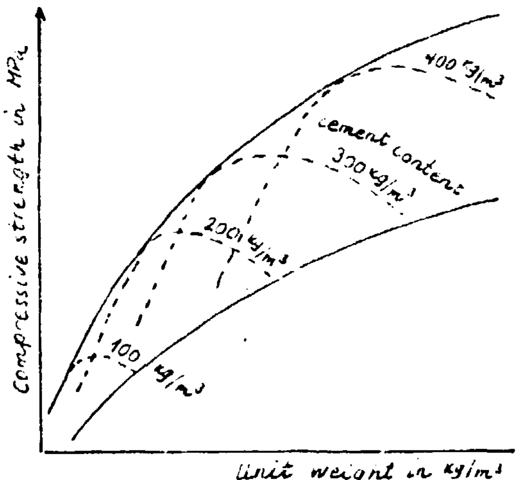


Fig. 9. Special relationship between unit weight and compressive strength depending on cement content

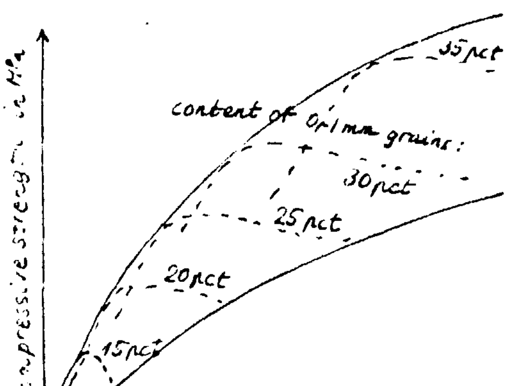


Fig 9. Special relationship between unit weight and compressive strength depending on grading

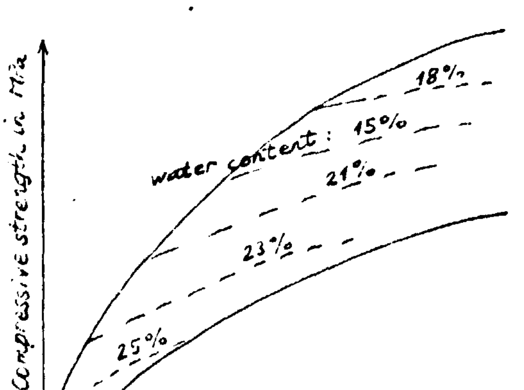


Fig. 10. Special relationship between unit weight and compressive strength depending on water content

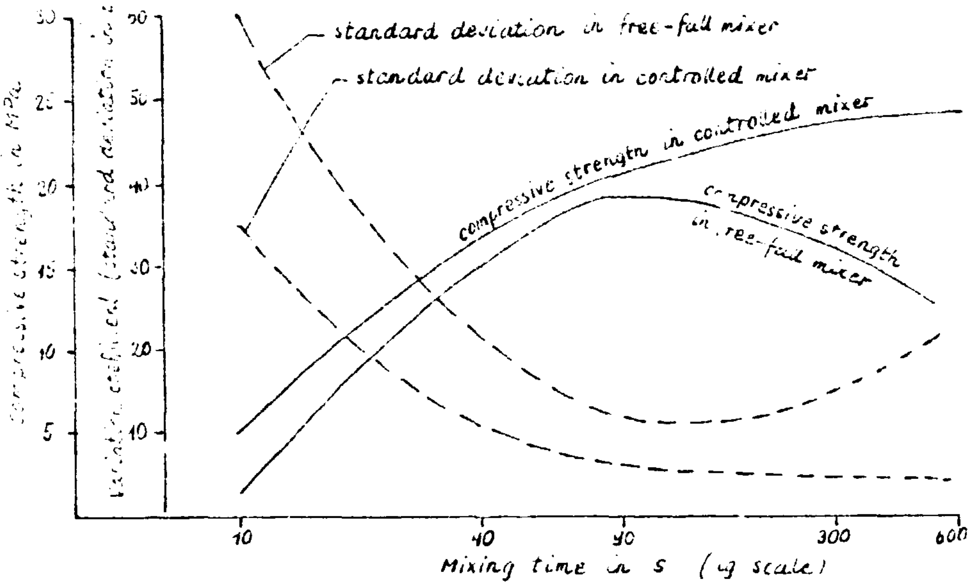


Fig. 11. Relationship among mixing time, compressive strength and standard deviation in different types of mixer

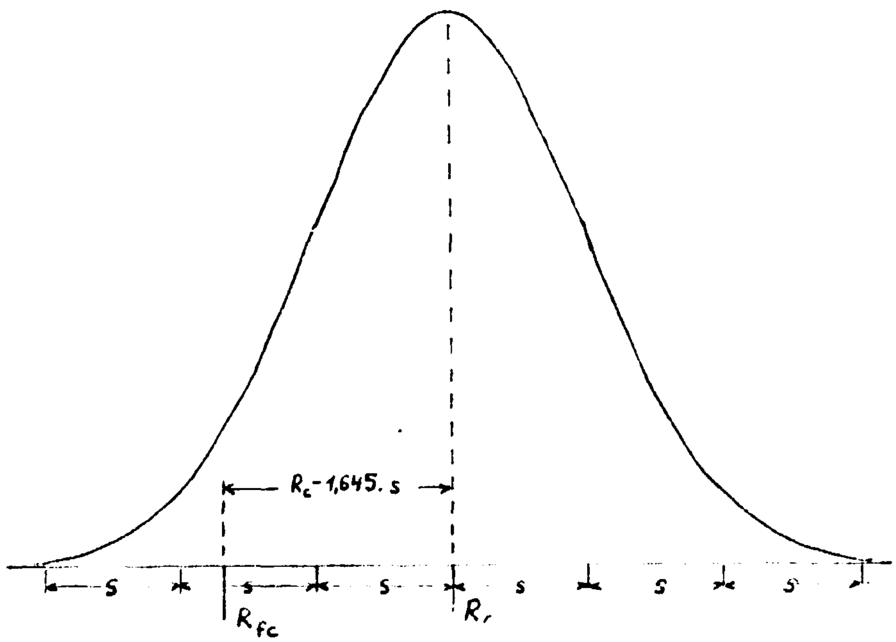


Fig. 12. Supposed frequency distribution for concretes (Gauss-curve)

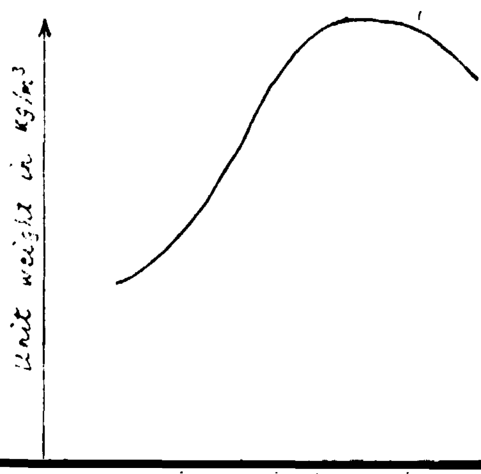


Fig. 13. Relationship between water content and unit weight of concrete by unchanged compacting effect

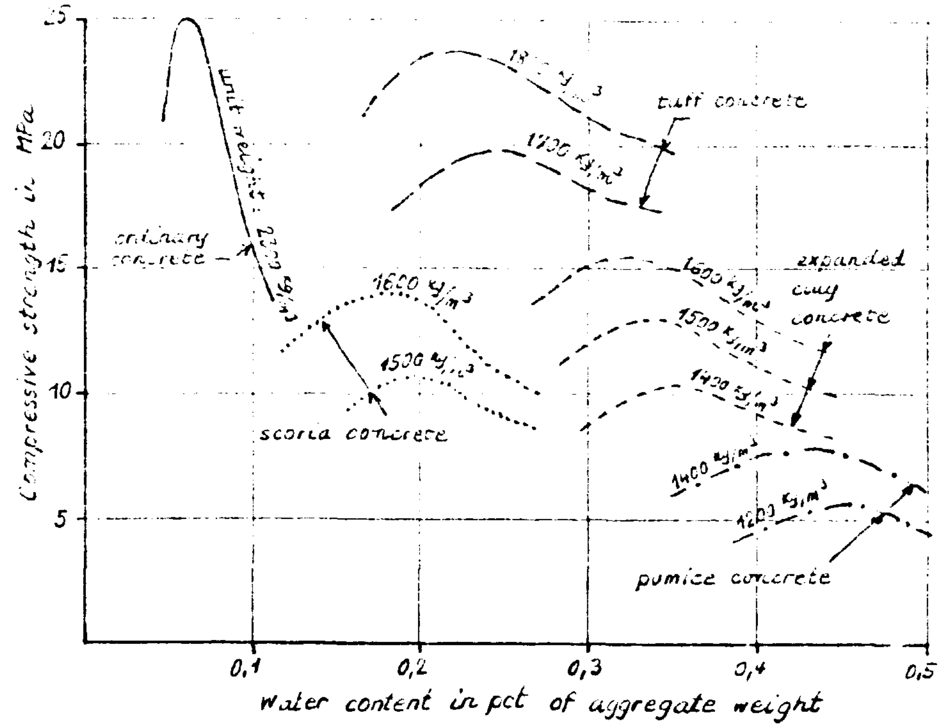


Fig. 14. Relationship between water content and compressive strength depending on type of aggregate

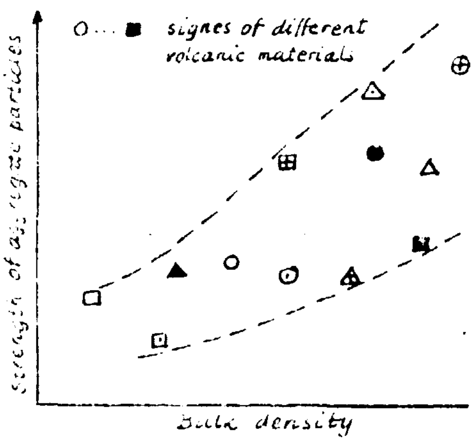


Fig. 15. Sketch for evaluation of investigation of materials

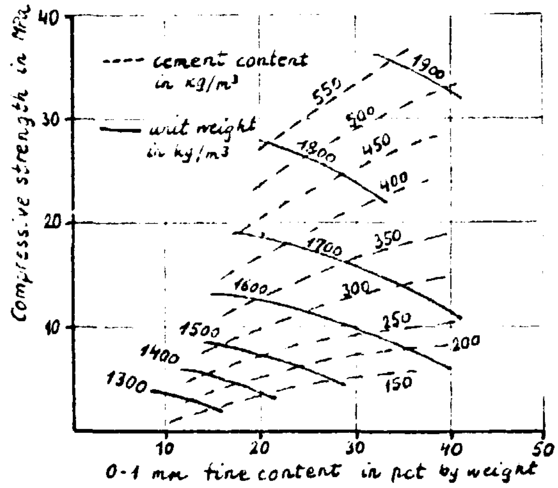


Fig. 16. Relationship among fine content, cement content, unit weight and compressive strength

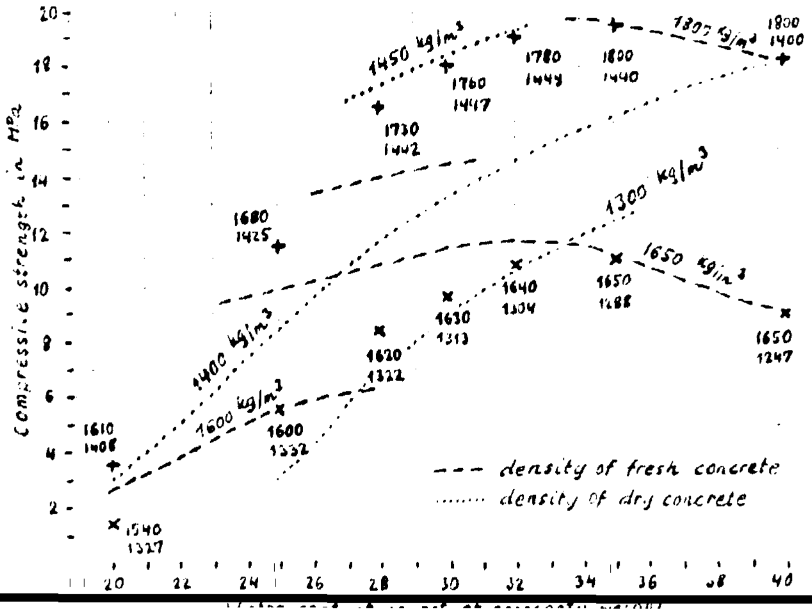


Fig. 17. Relationship between water content and compressive strength depending on unit weight of fresh and dry concrete (plotted from data of Table 4.)

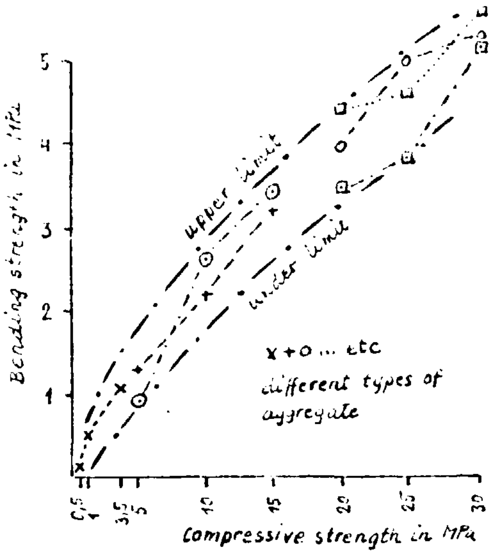


Fig. 18. Example for processing data of bending strength investigations

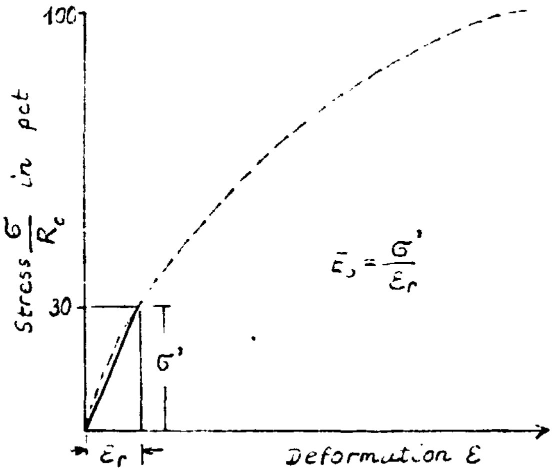


Fig. 19. Young - modulus

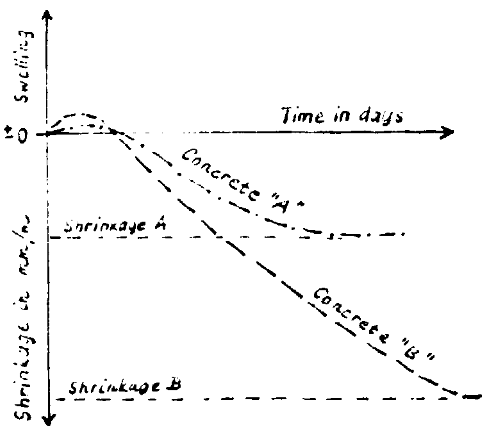


Fig. 20. Drawing Shrinkage

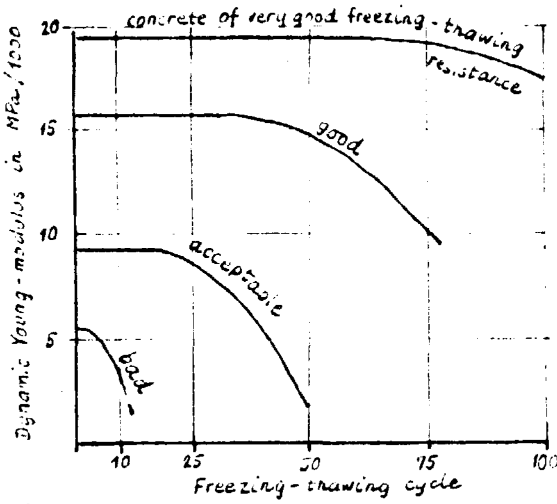


Fig. 21. Freezing - thawing resistance

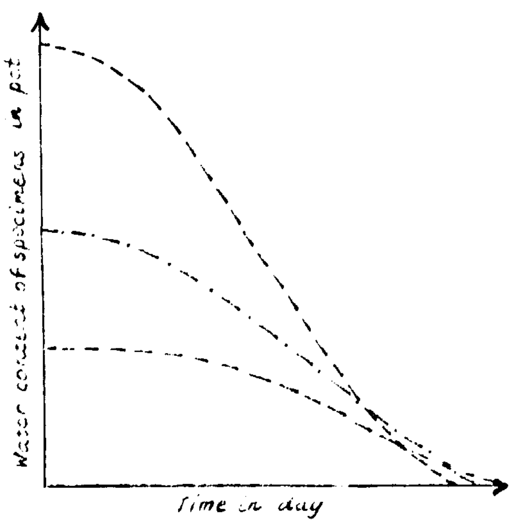


Fig. 22. Investigation of water desorption

A N N E X 5

INVESTIGATION OF POZZOLANIC ACTIVITY

1.- INTRODUCTION

Latent hydraulic materials (hydraulites) are materials that in themselves possess little or no cementititious value but will, in finely divided form and in presence of water, react chemically with calcium hydroxide at oridnary temperatures to form compounds possessing cementitious properties IN other words, the hardening energy is dormant and becomes active under the influence of an activator, such as calcium hydroxide or some other strong alkaline compound. When a latent hydraulic material is blended with portland cement and water, it becomes activated by the calcium hydroxide developed during the hydration of cement. The same process goes on when the latent hydraulic material is mixed with calcium oxide and water,

The setting and hardening processes, the function of chemical and physical properties are not completely known, generally the most important features for promoting the hydraulic activity are as follows:

- the vitreous state of hydraulite, since in this state the energy content of materials is the highest
- the lattice structure of zeolite which represents the zeolitic bound of water, the ion change and absorption capacity of materials
- the metakaolin decomposition which yields hydraulic activity of heated materials (e.g. ground brick)
- the basic agents which makes formation of calcium silicates and aluminates possible
- the acid agents (active silicic acid) mainly in pozzolans
- hydrate water content (though importance of that is recently discussed by different authors).

2/...

Due to the many influencing factors and their discussed effects, the setting capacity of the hydraulites can only be determined exactly by physical investigations. The principal of methods can be seen in Annex 1 Chapter
Chapter 4.3.

2.- INVESTIGATIONS

According to Annex 2, the materials were investigated for purpose of making hydraulic lime. The required fineness of grains ground from volcanic materials would have had to be about 4000 cm^2/g in specific surface, i.e. maximum grain size of about 60 µm. Because of difficulties in milling, it had to be satisfied with 100 µm in maximum grain size and with about 2000 cm^2/g in specific suface (belonged to this grain size).

The volcanic materials were ground in the laboratory of Ministry of Communication, the fine grains were transported to the Industrial Testing, Research and Development Centre. The cement laboratory of this Centre is well equipped: mixer, stamping table (or rather: shaking table) and suitable quantity of moulds (4x4x16 cm) are available.

Mixtures were made with mixing ratio of 1:3:0.7 (binder:sand:water). The binder was produced from ground pozzolan, hydrated lime and plaster of Paris in different ratios, as follows (by part in weight):

Serie 1: 0.67 Hydrated lime, 0.3 pozzolan, 0.03 plaster
Serie 2: 0.57 hydrated lime, 0.4 pozzolan, 0.03 plaster
Serie 3: 0.47 hydrated lime; 0.5 pozzolan, 0.03 plaster
Serie 4: 0.37 hydrated lime, 0.6 pozzolan, 0.03 plaster

Due to the limited quantity of ground pozzolan, it had to be satisfied with these four series instead of proposed series in Annex 1, Chapter 5/B and Annex 2 Chapter 4.3.

The weighed hydrated lime, pozzolan and gypsum were mixed by hand and sand was added to it. The dry materials were mixed in mechanical mixer during 15 s then with water during further 45 s. From one serie with each pozzolan 3 prisms were compacted on shaking table.

3/...

The fresh specimens were placed over water, after 7 days taken out from moulds, wetted and storaged in laboratory room.

Signes and compositions of series can be seen in Table 1.

Quantity of materials used to the first series (A1, A2, B and C) were not enough to three specimens of full dimensions therefore in the Research Center, additional fine grains had to be ground for making utilization of increased quantity possible.

The bending and compressive strength of specimens were investigated in 14 days. The data can be seen in Table 2 According to the experiences, the hydrated lime - plaster - possolan mixtures harden more slowly than the cement mortar, in 14 days, 50 pct of 28 days compressive strength can be expected. Therefore the data of Table 2 can be transformed into 28 days according to Table 3.

3.- EVALUATION

Mortars canbe produced with different binders. By using lime, the mortars have compressing strength of 0.4-1MPa if the lime: sand ratio comes to 1:4 or 1:3 with mixture of lime and cement (lime:cement ratio is 1:0.2 or 1:0.4) can be made mortars with compressive strength of 1-5MPa. If the binder is cement only (1:4 cement: sand ratio), the compressive strength of mortar comes to 5-10 MPa.

For displacing cement or for improving properties of mortar, hydraulic lime, i.e. mixture of hydrated lime and latent hydraulic material can be used. The goal of the investigation carried out was to determine the latent hydraulic properties of the Syrian volcanic materials. The results of investigations are summarized in Fig. 1.
According to this Figure, mortars produced with lime and ground volcanic material from Racca have compressive strength of about 5 MPa.

If the hydraulic is from Shahba, compressive strength of mortars will be about 4 MPa and hydraulit made from Hassake material, compressive strength of about 3MPa can be expected.

In the Hungarian Standard, the hydraulites are classified into five groups according to the compressive strength in 28 days:

Group	I	II	III	IV	V
Compr. strength at least (in MP)	10	7	4	2.5	1.5

The method of investigations prescribed in the Hungarian Standard is similar (tough not the same) as in the case of the investigations reported, therefore the above data can be employed for evaluation. Consequently, the volcanic materials investigated can be classified as follows:

Material from Racca	III group
Material from Shahba	IV group
Material from Hassake	V group

It has to be mentioned that the specific surface of the material used to these investigations did not satisfy the requirements (it was about 2000 cm^2/g instead of about 4000 cm^2/g) consequently the results are informatory only.
Not withstanding that the investigations have some uncertainty because of the lower specific surface, it can be stated, that using the ground volcanic materials investigated for making hydraulic lime is very promising.
Therefore detailed investigations of every Syrian volcanic material can be recommended.

Table 1. Signes and compositions of the series

Deposit	Signe	Hydrated lime g	Ground pozzolan g	Plaster of Paris g	Limestone sand g	Water
Hassake	A1	224	100	20	1004	201
	A2	224	100	10	1004	234
	B	191	134	10	1004	234
	C	157	167	10	1004	234
	D	137	222	10	1109	259
Racca	E	248	111	10	1109	259
	F	211	148	10	1109	259
	G	174	185	10	1109	259
	H	137	222	10	1109	259
Shahba	I	248	111	10	1109	259
	K	211	148	10	1109	259
	L	174	185	10	1109	259
	M	137	222	10	1109	259

Table 2. Results of investigations

Signe	Unit weight at testing in kg/m³	Bending str. in 14 days,	Compressive strength in MPa
A1	The specimens could not be investigated		
A2	1826	0,48	1,3
B	1880	0,53	1,5
C	1834	0,53	1,5
D	1853	0,62	1,3
E	1853	0,67	2,4
F	1879	0,81	2,7
G	1849	0,81	2,7
H	1868	0,97	2,8
I	1785	0,57	1,5
K	1876	0,56	1,7
L	1803	0,59	2,3
M	1829	0,77	2,1

Table 3. Strengths in 28 days (calculated data)

Signe (material of Hassake)	A2	B	C	D
Compressive strength in MPa	2,6	3,0	3,0	2,6
bending strength in MPa	1,0	1,1	1,1	1,2
Signe (material of Racca)	E	F	G	H
Compressive strength in MPa	4,8	5,4	5,4	5,6
Bending strength in MPa	1,3	1,6	1,6	1,9
Signe (material of Shahba)	I	K	L	M
Compressive strength in MPa	3,0	3,4	4,6	4,2
Bending strength in MPa	1,2	1,1	1,2	1,5

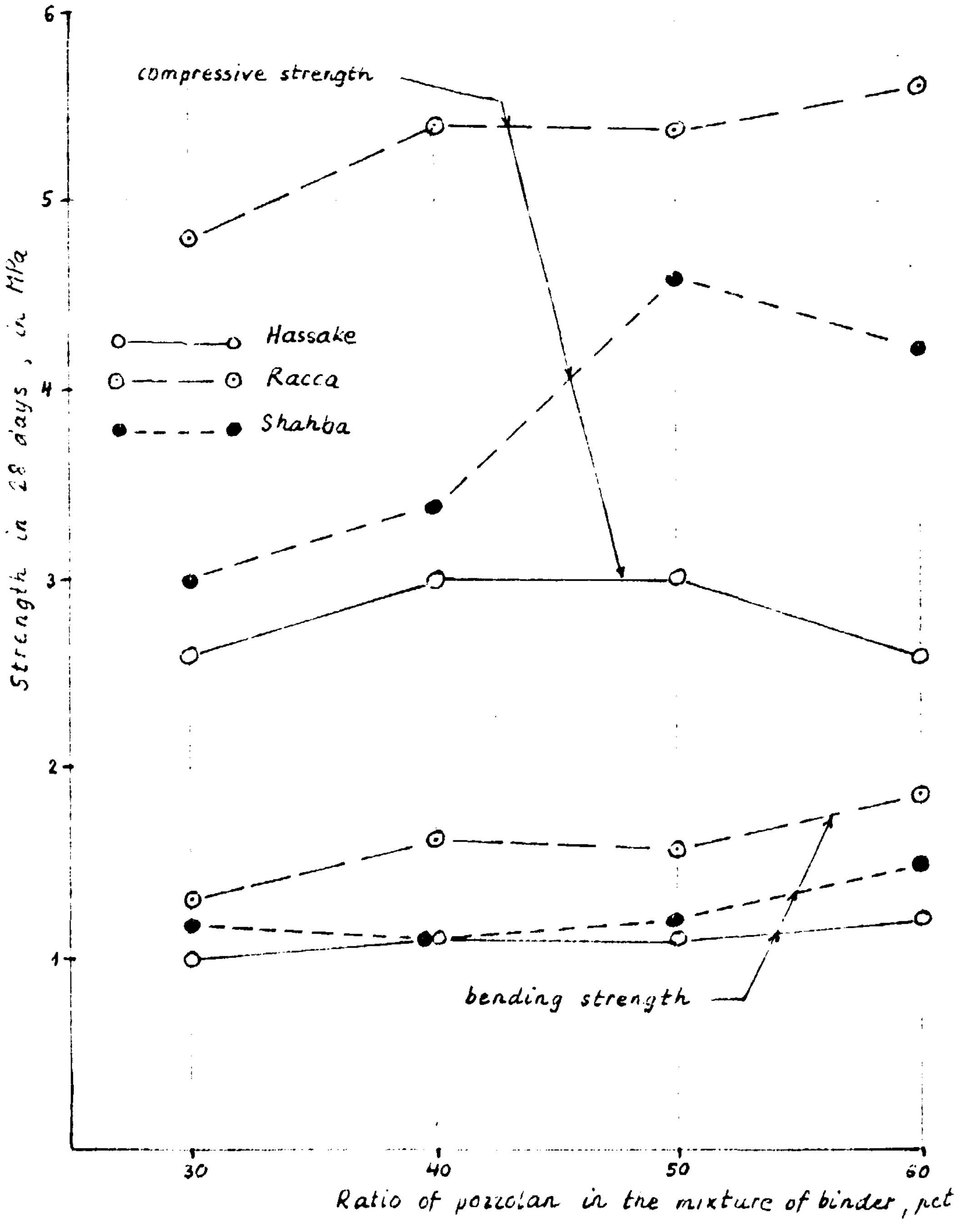


Fig. 1. Relationship between the pozzolan ratio and the compressive strength

ANNEX 6.

DEMONSTRATIVE ELEMENTS

Design of mould for making demonstrative elements can be seen in Figures (1) and (2).

The first element was made on 20th October with volcanic cinder of Shahba. The ingredients of concrete were mixed by hand in two batches. Quantities of ingredients :

	1. batch:	2. batch:
cement	55 kg	38,5 kg
aggregate of Shahba	103 kg	72,1 kg
sand (0-1 mm)	28 kg	19,6 kg
water	28 kg	19,6 kg
	214 kg	149,8 kg

The material was exactly enough for the element of $(150 \times 90 \times 20) - 10\,500 = 259\,500\ cm^3 \approx 0,26\ m^3$ in volume. Unit weight of the fresh concrete :

$$\frac{214 + 149,8}{0,26} = 1400\ kg/m^3$$

Composition of concrete :

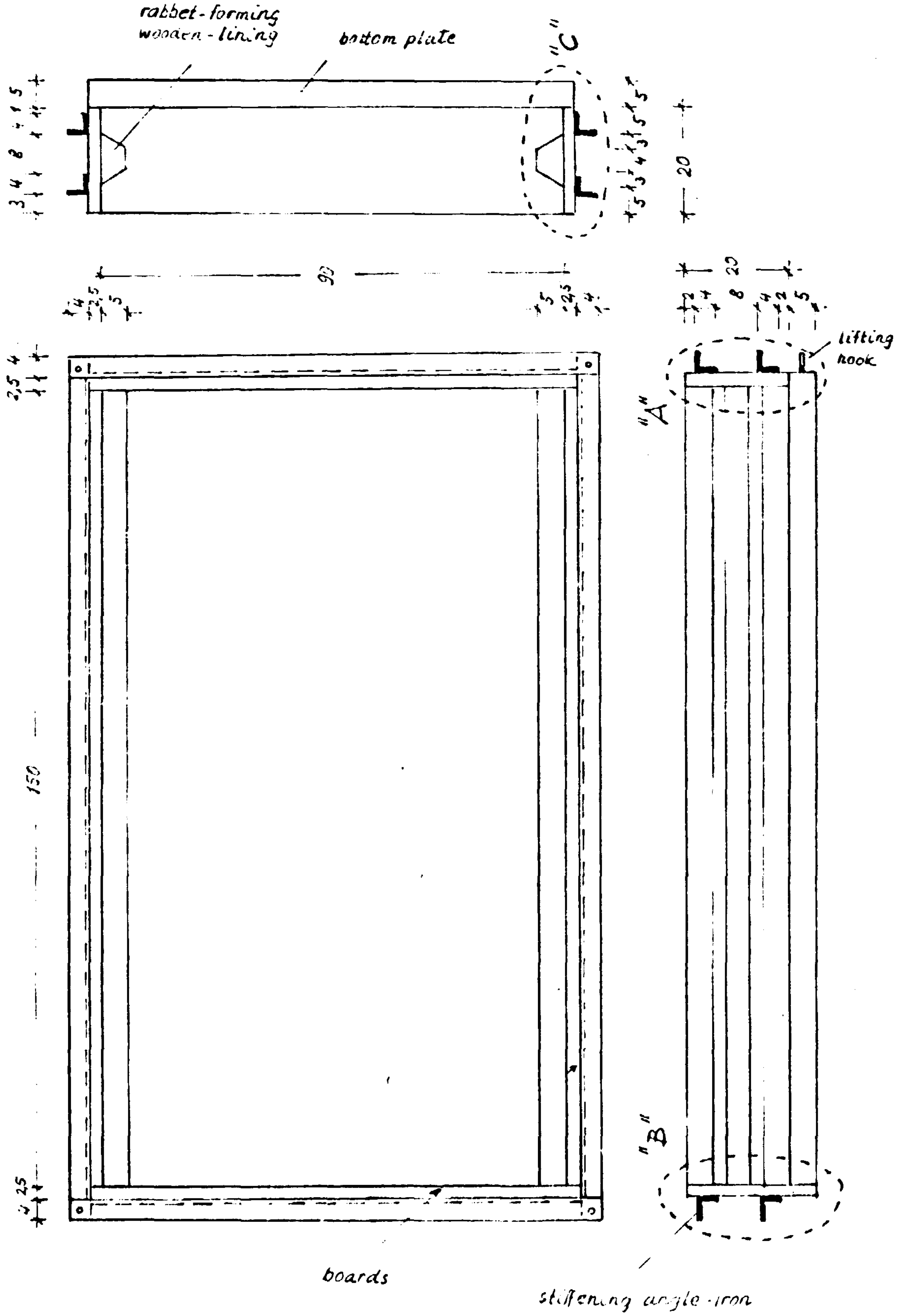
cement	360	kg/m^3
aggregate of Shahba	674	-"-
sand (0-1 mm)	183	-"-
water	183	-"-
	1400	kg/m^3

Figure (1)

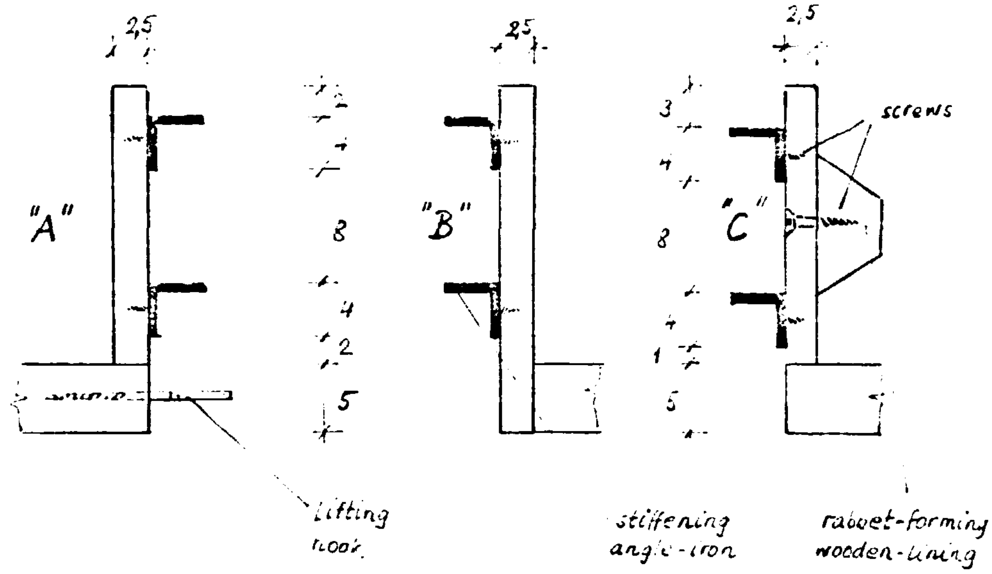
Design of mould for blocks

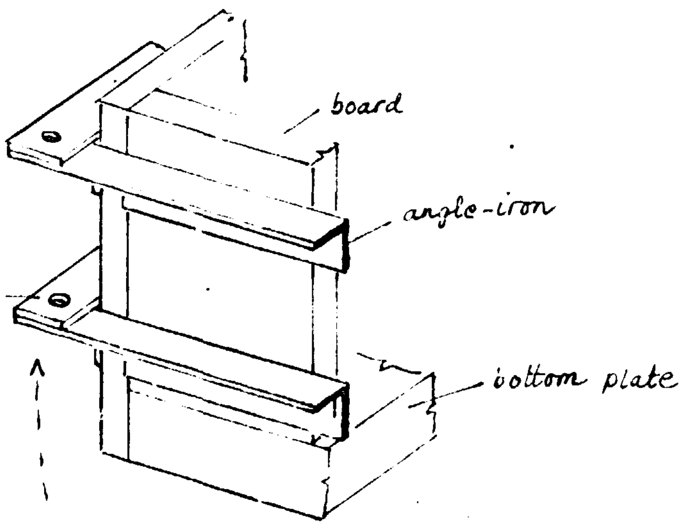
Measures in cm

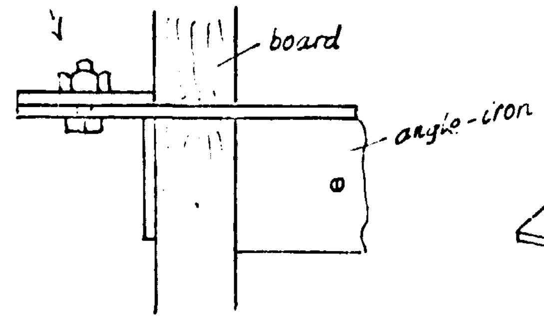
1:10



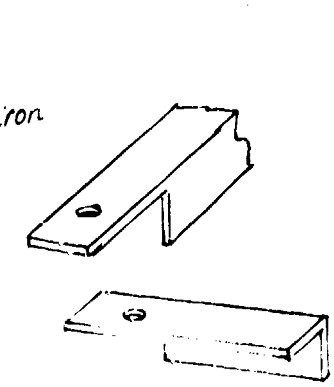
Parts of the mould







fastening with screw



ends of angle-irons