Mansoura Engineering Journal

Volume 14 | Issue 2 Article 5

5-25-2021

# Improving Properties of Lightweight LECA Concrete by Partial Replacement with Gravel.

A. Abd El-Reheem
*Associate Professor of Civil Engineering Department, Faculty of Engineering, Mansoura University, Mansoura, Egypt.*

M. Kamal
*Associate Professor of Reinforced Concrete Department, Building Research Centre Cairo, Egypt.*



## Recommended Citation

Abd El-Reheem, A. and Kamal, M. (2021) "Improving Properties of Lightweight LECA Concrete by Partial Replacement with Gravel.," *Mansoura Engineering Journal*: Vol. 14 : Iss. 2 , Article 5.
Available at: https://doi.org/10.21608/bfemu.2021.172228

Mansoura Engineering Journal (MEJ) Vol. 14,No.2,Dec. 1989 

# IMPROVING PROPERTIES OF LIGHTWEIGHT LECA CONCRETE BY PARTIAL REPLACEMENT WITH GRAVEL

تحسين خواص الخرسانة الخفيفة المصنعة من الليكا بالاحلال الجزئي بالزلط

A. H. Abd El-Reheem

Associate Professor
Civil Eng. Dept.
Faculty of Eng.
El-Mansoura Univ.

M. M. Kamal

Associate Professor
Reinforced Concrete Dept.
Building Research Centre
Cairo, Egypt

الخلاصة : يشتمل هذا البحث على دراسة الخواص الطبيعية و الميكانيكية لخلطات خرسانية استخدم فيها الركام الخفيف من الطين المنفوش والمعروف تجاريا باسم الليكا. لقد تم دراسة مائة وخمسة خلطة خرسانية في هذا البحث. الركام المستخدم في الخلطات الخرسانية كان خليطا من الليكا و الرمل و الزلط بنسب مختلفة . تم استخدام مقاسين من ركام الليكا احدهما ذو مقاس ٢ الى ٤ مم كركام صغير والاخر من ٤ الى ١٢ مم كركام كبير بنسب مختلفة مع الرمل و الزلط. اشتملت بعض الخلطات على زلط فقط او ليكا فقط مع الرمل للمقارنة . خواص الخرسانة التي تم دراستها هي الوزن الحجمي و النسبة المئوية للامتصاص ومقاومة الضغط و الانحناء، ومعايير المرونة . تم دراسة مقاومة التماسك بين الخرسانة و الصلب. توصلت الدراسة الى انه يمكن الحصول على خرسانات ذات وزن حجمي خفيف نسبيا مع مقاومة ضغط مناسبة للاعمال الانشائية باحلال نسبة من الزلط والرمل بركام الليكا وامكن عمل منحنيات يمكن الاسترشاد بها لمصممي الخلطات الخرسانية .

## SYNOPSIS

This research was conducted to study the mechanical and the physical properties of concrete mixes made of light weight expanded clay aggregates with trade name (LECA). One hundred and five concrete mixes were investigated. The aggregate used was a mixture of "LECA" and gravel with different proportions. Concrete mixes with "LECA" only or gravel only were tested for comparison. The main properties of the concrete mixes tested in this investigation were the unit weight, absorption percentage, compressive strength, flexure strength and modulus of elasticity. Bond strength between concrete and steel was also investigated. It was found that an adquate strength with reasonable unit weight and absorption percentage of concrete could be achieved by partial replacement of gravel in the concrete mix by "LECA".

## INTRODUCTION

During the last few decades light weight concrete has been known as an advantageous alternative for the traditional concrete in many counteries. Its applications have been increasingly established elsewhere. Regarding the concrete industry in Egypt, the lightweight concrete is considerably limited. Among the most attractive advantages of light weight concrete are; reduction in dead loads, lower handling costs, faster building rates and more feasability of constructing on weak soils. Light weight concretes were classified as those having densities between 300 and 2000 kg/m$^3$ (1). Generally, light weight concrete could be produced by creating air bubbles in the concrete mix, omitting the fine size aggregate from the concrete mix or by replacing the gravel or crushed rock by light weight aggregate (1-6). Among the different lightweight aggregates used in the concrete industry are; furnace clinker, foamed blastfurnace slag, exfoliated vermiculite, expanded perlite, pumice, sintered pulverised-fuel ash and expanded clay and shale (7).

This research includes a study of the physical and mechanical properties of light weight concrete using a locally produced light weight expanded clay aggregate with trade name "LECA". The concrete mixes tested in this investigation were made of combined aggregates of LECA, gravel and sand.

## EXPERIMENTAL WORK

One hundred and five (105) concrete mixes with different percentages of sand, gravel, fine and coarse "LECA" were investigated. Cement content of 350 kg/m$^3$ of concrete was used. The characteristics of the material used were investigated. The unit weight, absorption percentages, compressive strength, flexure strength and modulus of elasticity of different mixes were investigated. Three hundreds and fifteen concrete cubes, nine prisms and twenty seven cylinders were tested in this research.

Table (1) shows the scheme of the different concrete mixes tested in this investigation.

## CHARACTERISTICS OF THE MATERIALS USED

The materials used in this work were ordinary Portland cement, sand, gravel and "LECA". Mild steel bars of 16 mms. diameter were used in bond tests.

1. Cement:

Ordinary Portland cement brought from Toura cement factory was used in this investigation. Tests carried out on that cement showed that its properties fulfiled the requirements of the Egyptian standard specification concerning the setting time, fineness and strength as shown in table (2).

2. Sand:

Sand used was brought from Khatatba quaries which was clean, almost free from impurities and does not contain more than 1% by volume silt, loam or clay. Table (3) shows the characteristics of the used sand, table (4) shows the sieve analysis of the used sand.

3. Gravel:

The gravel used was obtained from El-Sharkia quaries with nominal maximum size of 19 mms. Table (5) shows the characteristics of the gravel used.

4. Light weight expanded clay aggregate (LECA):

"LECA" was brought from the National Cement Company which was produced by burning desert shale clay slurry with liquid fuel in rotary kiln. The LECA particles sizes ranged from 2 mms to 12 mms. The particles of the "LECA" with sizes of 2 to 4 mm were considered as fine "LECA" (FL), however the particles with sizes of 4 mms to 12 mms were considered as coarse "LECA" (CL). The characteristics of the LECA used are shown in Table (6).

## II. Concrete Mixing and Compaction

Preliminary slump tests were carried out using different water/cement ratios among which w/c ratios of 0.5 was chosen for all the concrete mixes tested. This ratio gave plastic mixes with slump of 40-100 mm when low "LECA" contents were used. However, dry mixes with 10-15 mm slump were obtained for most of the mixes with high coarse "LECA" content. During adding the mixing water it was observed that fine and coarse LECA particles float to the top of the concrete mix. However, mixing of the dry constituents was firstly carried out followed by thorough addition of mixing water in successive small quantities. Carefull compaction was carried out. Nevertheless segregation and inhomoginity of the concrete casting using LECA occured as can be seen in Figs. (1-4). Figures 2,3 and 4 show concrete cubes with different "LECA" contents.

## Analysis and Discussion of Test Results

Figures (5-a to c) show the unit weight of the different concrete mixes cured in air for 28 days after casting. Out of these figures it can be drawn that the unit weight of concrete decreases by replacing the gravel by coarse LECA. Higher reduction in the unit weight of concrete could be achieved if also sand is replaced by fine LECA. Mixes of higher coarse to fine aggregate ratios indicate lower unit weights. The average unit weight of the traditional concrete mixes with gravel as coarse aggregate and sand as fine aggregate which were tested in this investigation is about 2463 kg/m$^3$. However, the average unit weight of the concrete mixes containing completely LECA as combined aggregates is about 1367 kg/m$^3$. A unit weight of 1275 kg/m$^3$ could be achieved with a concrete mix with purely LECA as inert filler where the coarse to fine aggregate ratio was 3:1.

Figures (6-a to e) show the absorption percentage of the different concrete mixes cured in air for 28 days after casting, dried in oven at 100°C for 48 hours and submerged in water for 24 hours. The gain in weight is expressed as the absorption percentage. It was found that higher absorption percentages were recorded for mixes containing higher percentage of LECA as fine and coarse aggregate. Tests showed very high absorption percentages for LECA aggregates (65%). However, concrete mixes made of LECA exhibted comparatively much lower absorption percentages of about 26% of that recorded for the LECA particles. On contrary, the concrete mixes made of sand and gravel exhibted much higher absorption percentages than the aggregetes used. The average absorption percentage of the concrete mixes made of sand and gravel as combined aggregates is about 3%. However, the average absorption percentage of those mixes made of LECA is about 16%. Absorption percentages ranged between these two figures for the mixes that contained a mixture of gravel, sand and LECA with different ratios.

Figures (7.a to e) show the compressive strength of the different concrete mixes at 28 days age. It is clear that replacing of gravel and sand with LECA decreases the concrete compressive strength. Concrete mixes containing sand and gravel only as combined aggregates showed an average compressive strength of about 200 $kg/cm^2$. However, those concrete mixes that contained LECA only showed an average compressive strength of about 67 $kg/cm^2$ which is extremely low. Values of compressive strength ranging between the above mentioned figures could be obtained by the partial replacement of sand and gravel by LECA in the concrete mix.

Figures (8-a to d) show that the compressive strength increases with the increase of the unit weight of the concrete mixe. The Egyptian Code of practice stated that the compressive strength of concrete used in structural purposes should be not less than 160 $kg/cm^2$. Figure (8-c) shows that compressive strength of 160 $kg/cm^2$ could be obtained by using a LECA / gravel mixure in the concrete mix which consequently has a unit weight of 1640 $kg/m^3$. This figure represents a reduction of 35% in the unit weight of the concrete mix including gravel only as coarse aggregate. Concrete commonly used in the Egyptian building sector is of an average compressive strength of 200 $kg/cm^2$. This figure could be obtained and in the same time unit weight of 1860 $kg/m^3$ could be achieved by partial replacement of gravel by LECA as in Fig. (8-c). This figure represent 26% reduction in the unit weight in comparison with the concrete mixes with gravel only as coarse aggregate. The reduction in unit weight of concrete affects greatly the dimensions of the carrying members and consequently the overall materials costs and the construction costs which depend mainly on the labour costs and period of establishment. Higher buildings could be achieved by lightweight concrete. Using lightweight concrete mix constructions on relatively weak soils becomes more promising. It is well-known that thermal conductivity of lightweight concrete is much less than ordinary concrete which causes great reduction in the consumption of energy needed for the air conditioning of the buildings.

The curves plotted in this research could be of great importance for the concrete mix designer as a guide for choosing a concrete mix for certain application with adequate unit weight and reasonable compressive strength.

Table (7) shows the different mechanical properties of three concrete mixes chosen out of the one hundred and five mixes tested in this investigation. The first mix represents the traditional concrete containing gravel and sand, while, the last mix represents the LECA concrete. The second mix in the table represents a concrete mix with a mixture of equal ratios of sand to fine LECA and gravel to coarse LECA. This table indicates that partial replacement of LECA by gravel and sand increases the mechanical and physical properties as well as increasing the flexural strength / compressive strength ratios, modulus of elasticity / compressive strength ratios and bond strength /compressive strength ratios.

## Conclusions

Out of this research study it can be concluded that a fairly light concrete with unit weight of 1275 kg/m$^3$ could be obtained by using LECA as combined aggregates for the concrete mixes. Unfortunately, this is followed by a very low compressive strength of 67 kg/cm$^2$ and very high absorption percentage of 19%.

The unit weight, absorption percentage and strength of concrete are largely inter-dependent; generally, the denser the concrete the less its obsorption percentage but the greater its strength.

Enhancement could be achieved in both the mechanical and physical properties of concrete by partial replacement of LECA by gravel and sand.

Concrete with 26% reduction in weight than the traditional concrete could be produced with compressive strength of 200 kg/cm$^2$ by partial replacement of LECA by gravel. This grade is commonly used in concrete industry in Egypt. The reduction in weight could be increased to 35% for those mixing with concrete compressive strength of 160 kg/cm$^2$.

The curves available in this research might be of great use in choosing concrete mixes with adequate unit weight and satisfactory strength.

Among the many applications of the lightweight concrete in the construction sector are; precast blocks, cavity external walls, non-load bearing walls, load bearing walls of low rising buildings, floor screeds and roof screeds.

## Referances

1. Cement and Concrete Association, "An Introduction to Lightweight Concrete", 1960.

2. Shetty, M. S., "Concrete Technology", S. SHAND Company Ltd. Ram Nagar, New Delhi, 1982.

3. ACI committe 304, "Batching, Mixing and Job control of Lightweight Concrete", 1982.

4. Neville, A. M., "Properties of Concrete", the English Language Book Society and Pitman, third Edition, 1982.

5. Comite Euro-International due Beton (CEB), "Light Weight Aggregate Concrete", the Construction press, 1979.

6. Abdel-Aziz, A. F., "Properties of LECA and Other Light Weight Materials and THeir Uses in Concrete", M. Sc. Thesis, Faculty of Eng., Ain Shams Univ., Egypt, 1986.

7. B. R. E. Digests "Building Materials, Essential information from Building Research Establishment" Medical and Tech. Pub. Comp. Ltd, MTP, Construction, Leonards House, Lancaster UK, 1975.

Table (1) Scheme of Concrete Testing

| Number of Mixes | FA: CA | G: CL | S: FL | Age of testing | Tested Property |
|---|---|---|---|---|---|
| 105 mix | 1:1<br>1:2*<br>1:3 | all Grav.*<br>75 : 25<br>67 : 33<br>50 : 50*<br>33 : 67<br>25 : 75<br>0 :100 | all Sand*<br>75 : 25<br>50 : 50<br>25 : 75<br>0 :100 | 28 days | - Slump<br>-Unit Weight<br>-Absorption%<br>-Comp. Strength<br>-Flex. Strength<br>-E<br>-Bond Strength |

- FA = Fine agg., CA = Coarse agg.
- G = Gravel, S = Sand, CL = Coarse LECA, FL = Fine LECA
- Three specimens were tested for each test
- Tests were carried on cubes 150mms sides for compression, beams of 100 x 100 x 500 mms for flexure, cylinders of 150 mms diameter and 300 mms height for "E" and bond tests
- Flexure strength , E and bond tests were carried out on three mixes only (*) (Pure grapvel and sand, equally mixed gravel, sand and LECA and pure LECA).

Table (2) Properties of Ordinary Portland Cement

| Test | Fineness ($cm^2/gm$) | Setting Time | | Compressive Strength ($kg/cm^2$) | |
|---|---|---|---|---|---|
| | | initial | Final | 3 days | 7 days |
| Test Result | 2890 | hr min<br>3 50 | hr min<br>6 45 | 190 | 265 |
| Limit of E. S. S. | 2250 | < 45 min | > 10 hr | < 180 | < 240 |

Table (3) Characteristics of the sand used

| Specific gravity | Unit weight of compacted sand $t/m^3$ | % Fine dust by volume | Finnes modulus |
|---|---|---|---|
| 2.63 | 1.72 | 1.0 | 2.67 |

Table (4) Sieve analysis of the sand used

| Sieve size (mm) | 4.76 | 2.83 | 1.41 | .707 | .354 | 0.177 |
|---|---|---|---|---|---|---|
| % Passing by weight | 94.5 | 88 | 75.5 | 43 | 5 | 1 |

Table (5) Characteristics of gravel used

| Specific gravity | Volume weight t/m³ | Compressive load (ton) | Absorption % 24 hrs in water |
|---|---|---|---|
| 2.6 | 1.7 | 12.60 | 0.5 % |

* The compressive load causes 10 mms compaction

Table (6) Characteristics of LECA

| Tested size | Specific gravity | Volume weight t/m³ | Compressive load (ton) | Absorption % 24 h in water |
|---|---|---|---|---|
| 2-4 mm | 0.90 | 0.57 | 3.0 | 65 |
| 4-12 mm | 0.70 | 0.33 | 1.8 | 52 |

* The compressive load causes 10 mms compaction

Table (7) Mechanical properties of tested concrete mixes at 28 days age after casting

| Sand / fine LECA | Fine / coarse LECA | Gravel / coarse LECA | comp. strength kg/cm² | Unit Weight kg/m³ | Absorp. % | Flexural Strength Kg/cm² | Mod. of Elas. (E) ton/cm² | Bond Str. Kg/cm² |
|---|---|---|---|---|---|---|---|---|
| 1:0 | 1:2 | 1:0 | 250 | 2500 | 3.0 | 48 | 250 | 20 |
| 1:1 | 1:2 | 1:1 | 175 | 1800 | 7.0 | 29 | 170 | 12 |
| 0:1 | 1:2 | 0:1 | 67 | 1275 | 19.0 | 20 | 70 | 8 |

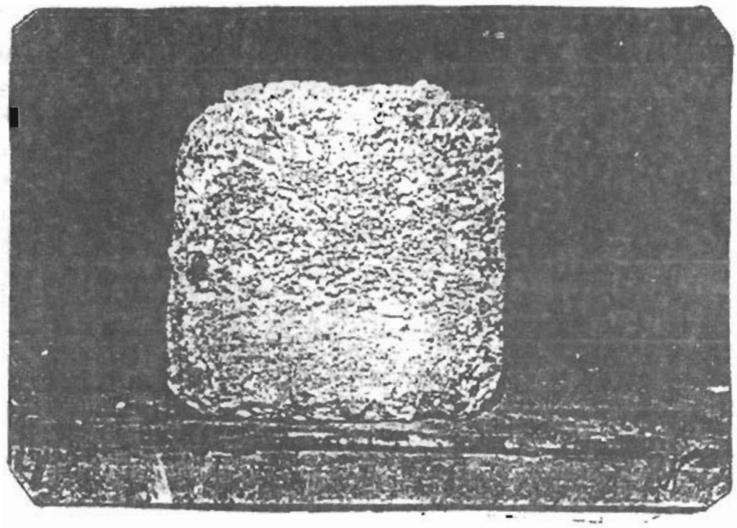


Fig. (1) Segregation of aggregate due to high W/C ratio and inadequate compaction. ("LECA" particles on the top)

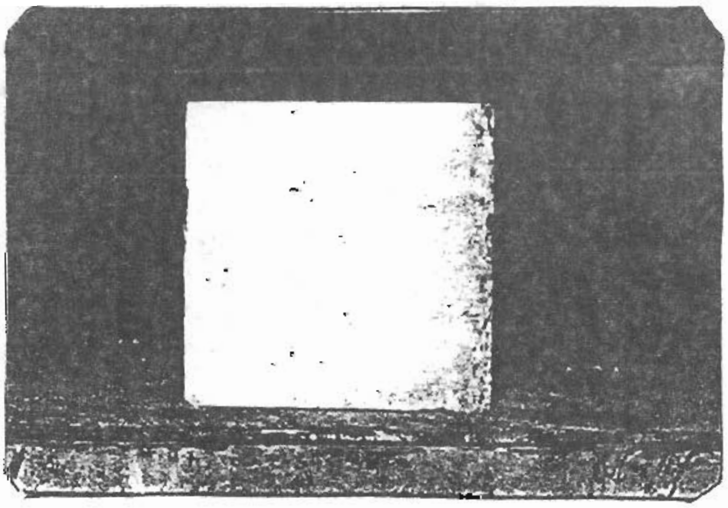


Fig. (2) Concrete cube with gravel only as coarse aggregate.

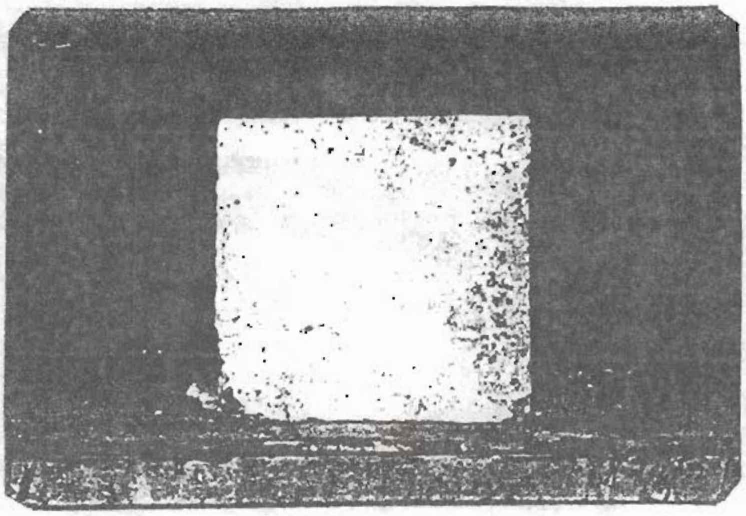


Fig. (3) Concrete cube with mixture of gravel and "LECA".

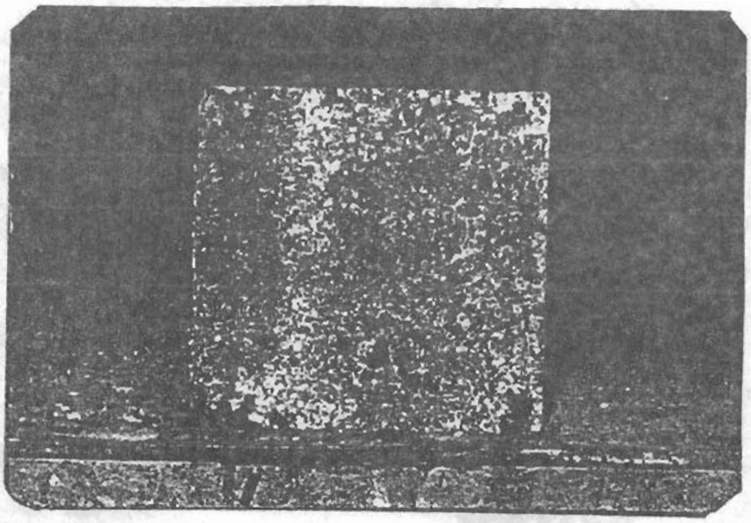
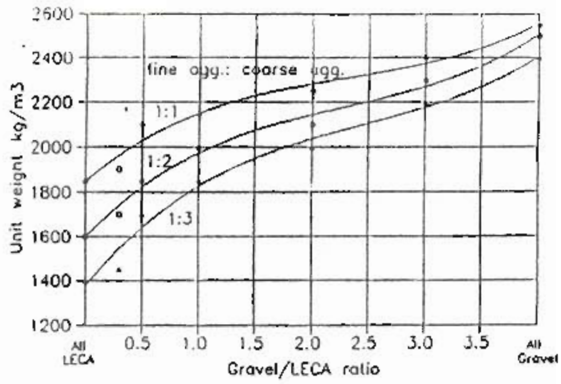
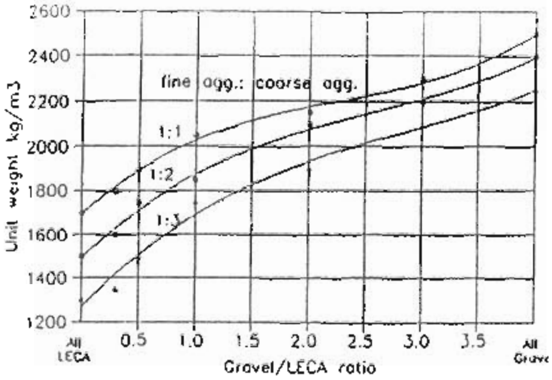


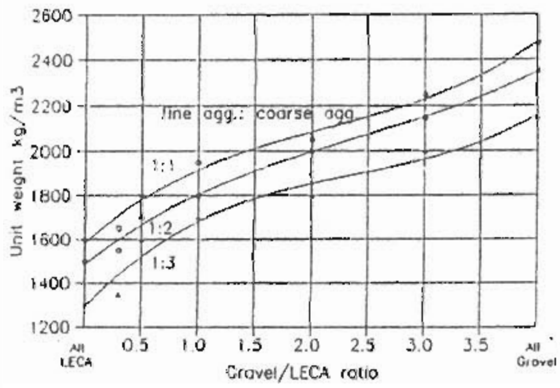
Fig. (4) Concrete cube with "LECA" only.



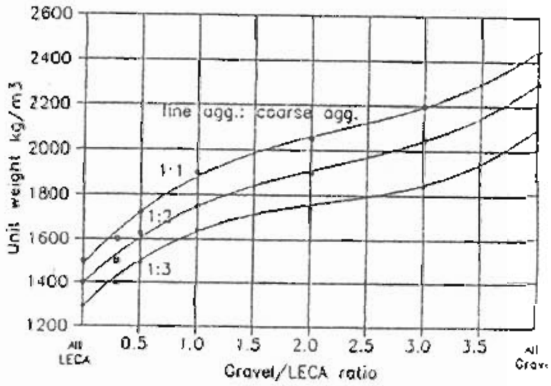

a - Sand:fine LECA 1:0



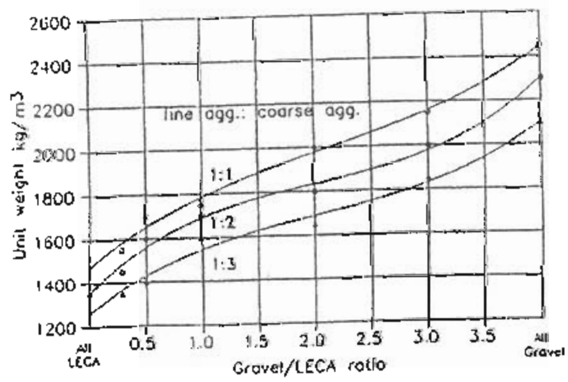

b - Sand:fine LECA 3:1




c - Sand:fine LECA 1:1




d - Sand:fine LECA 1:3




e - Sand:fine LECA 0.1

Fig. (5) Unit weight of LECA-Gravel concrete mixes

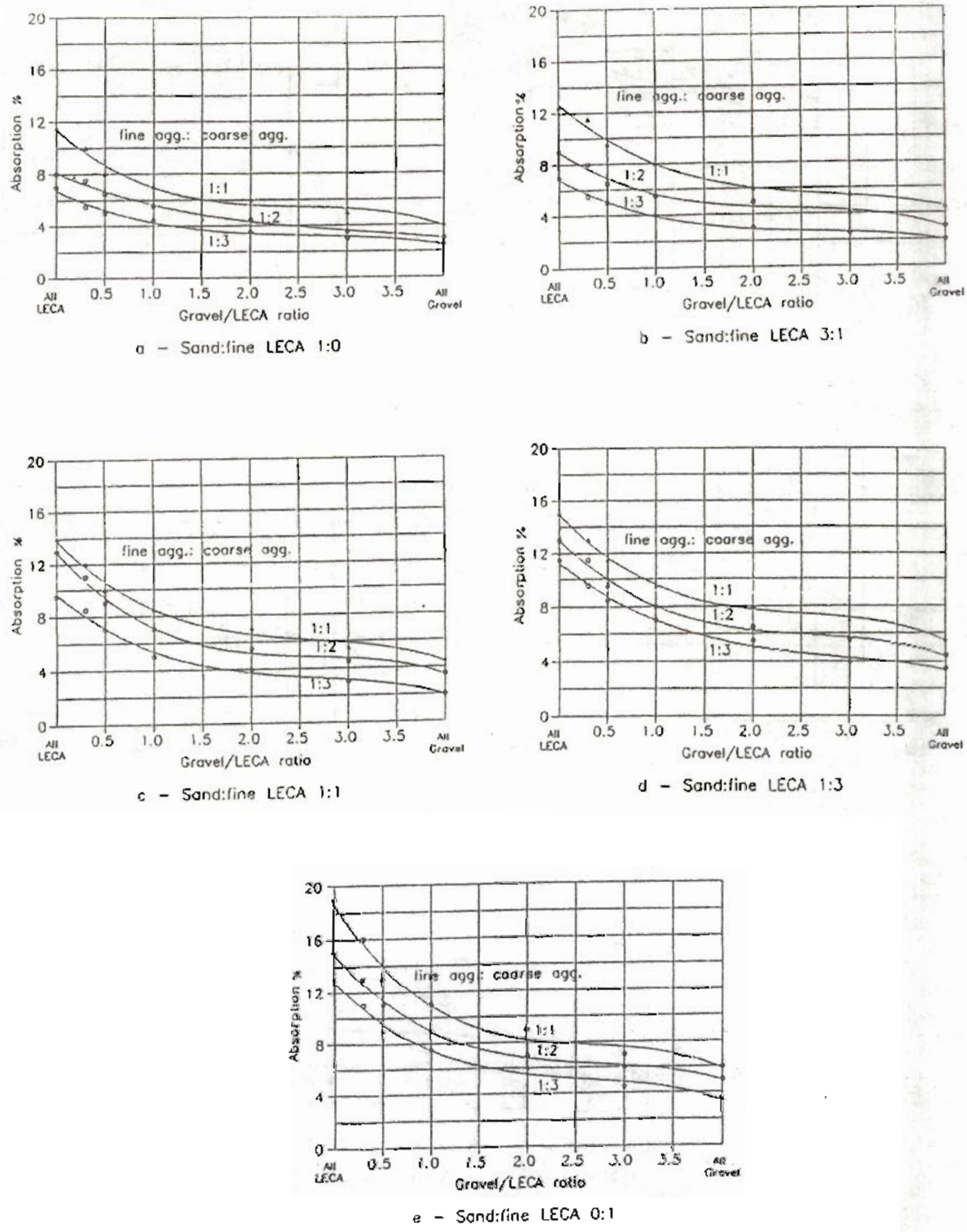



Fig. (6) Absorption Percentages of LECA-Gravel concrete mixes

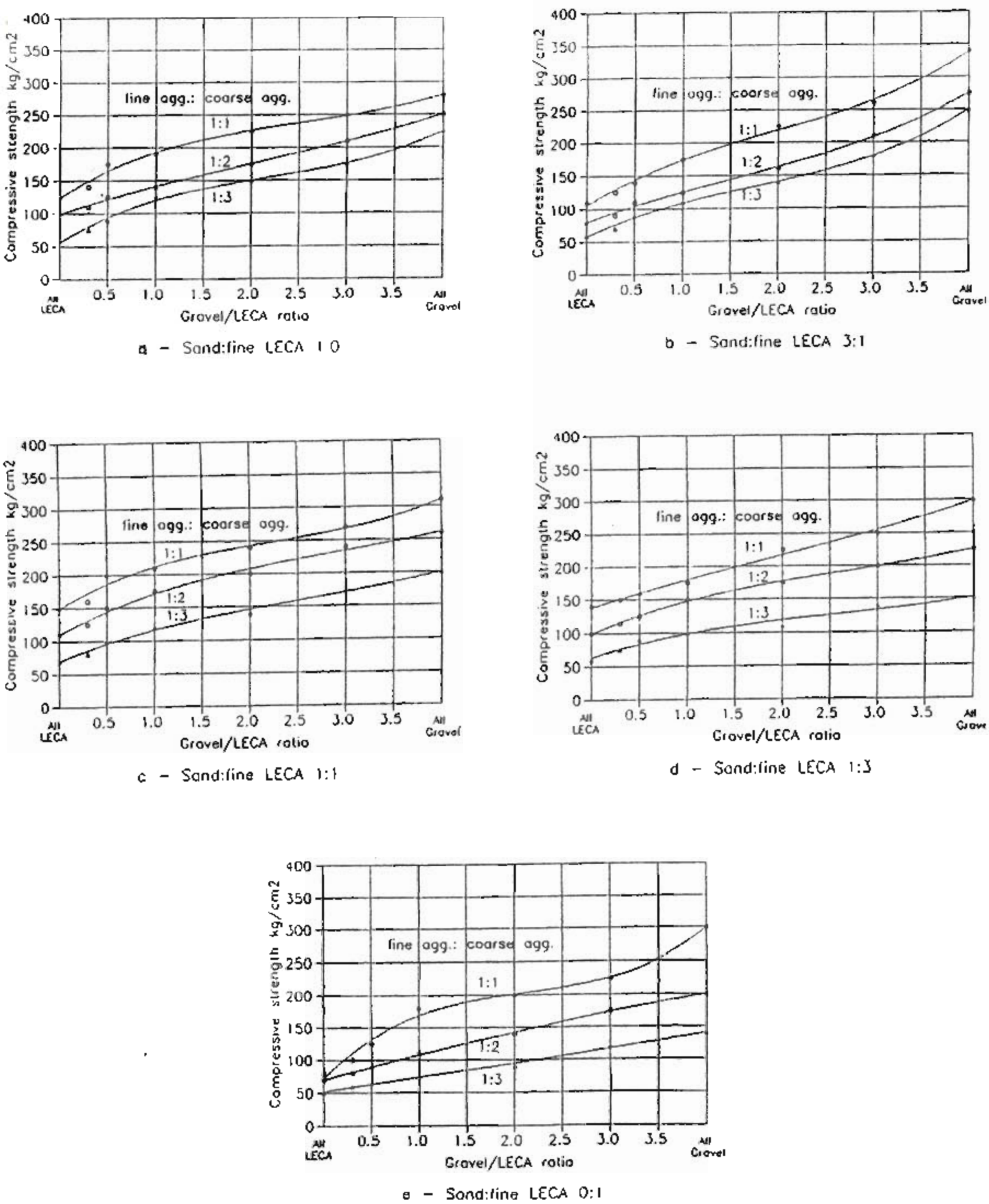
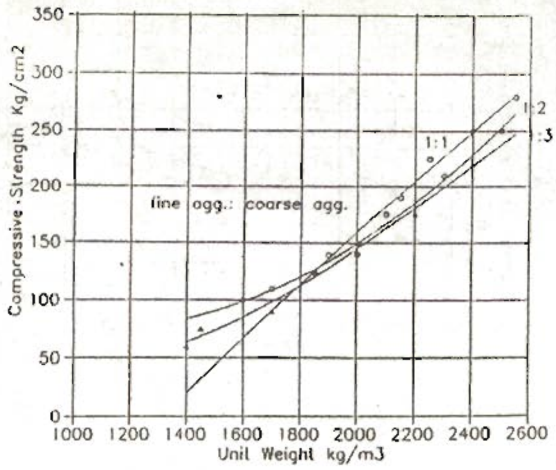
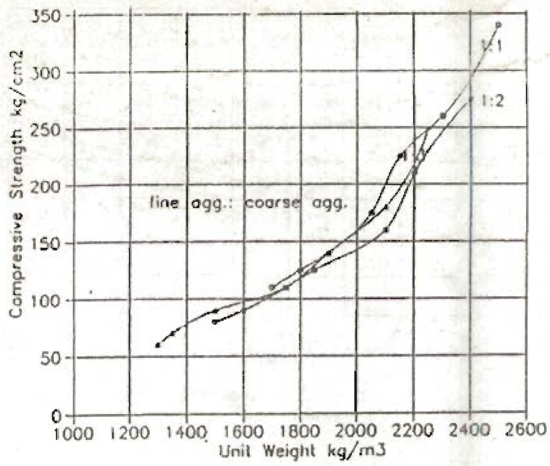


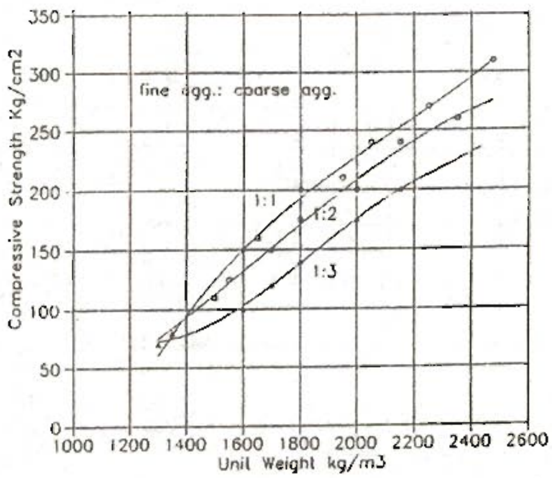

Fig. (7) Compressive strength of LECA-Gravel concrete mixes



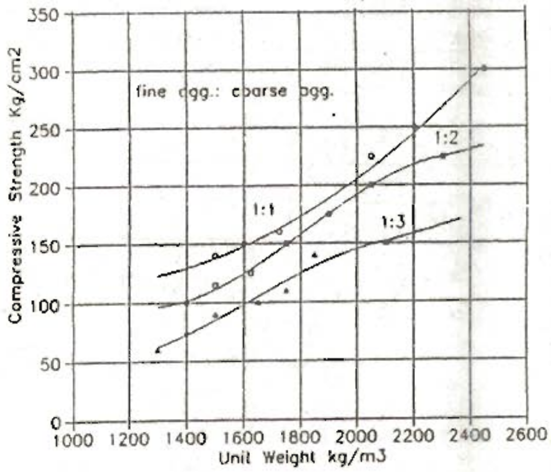

a – Sand:fine LECA 1:0



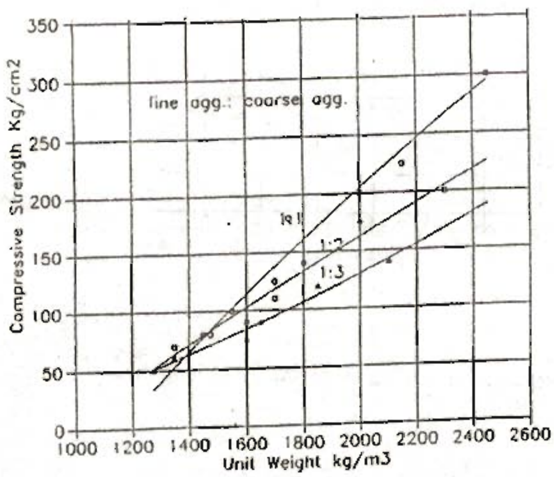

b – Sand:fine LECA 3:1




c – Sand:fine LECA 1:1




d – Sand:fine LECA 1:3




e – Sand:fine LECA 0:1

Fig. (8) Relationship between unit weight and compressive strength of LECA–Gravel concrete mixes.