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Properties of Green Concrete Mixes Utilizing Natural Egyptian Materials

خواص الخرسانة الخضراء(صديقة البيئة) باستخدام المواد الطبيعيةالمصرية

Reham M. Ibrahim, *Mohamed Y. Elshikh* and Abd EL-A zeez EL-Hlawany

KEYWORDS:
NEM; Metakaoline; Silica fume; Fly ash; LEED;Mix design; Mechanical Properties.

***الملخص العربي*:-اهتم البحث العلمي في الماضي وفي الوقت الحاضربتلوث البيئة لما له من اضرار علي صحة الإنسان. وذلك نتيجة للتقدم الصناعي المذهل الحادث في أواخر القرن الحالي. ويهدف هذا البحث العلمي إلي الإستفاده من المخلفات الصناعيه كبدائل جزئيه للاسمنت مثل الرماد المتطاير وغبار السيليكا وكذلك الكاولين الحراري وذلك للحصول علي خرسانه ذات مقاومه عاليه لاجهادات الضغط والشد عن طريق مواد رخيصه الثمن ومتوفره محليا بلأضافه لكونها صديق للبيئه وذلك بإضافة نسب مختلفه من وزن الاسمنت. وقد تم في هذا البحث دراسة تاثير هذه البدائل منفرده أو مجموعه من الاضافات اثنين أو ثلاثه معا كبدائل جزئيه من وزن الاسمنت وتم إجراء اختبار الضغط والشد لنسب مختلفه من هذه البدائل وقد تبين تاثيرها الملحوظ علي قوة ومتانة الخرسانه وذلك بمقارنتها بخلطه الخرسانه العاديه.**

وقد تم في هذا البحث دراسة المراحل المختلفة حيث تم تقسيم بدائل الاسمنت كاحلال جزئي الي ثلاثة مراحل:

-المرحله الاولي دراسة تاثير استبدال نوع واحد من غبار السليكا أو الرماد المتطاير أو الميتاكولين علي خصائص الخرسانه.

-المرحله الثانيه دراسة تاثير استبدال نوعين من غبار السليكا و الرماد المتطاير و الميتاكولين علي خصائص الخرسانه.

-المرحله الثالثه دراسة تاثير استبدال ثلاثة أنواع من غبار السليكا و الرماد المتطاير و الميتاكولين علي خصائص الخرسانه.

- وقد أظهرت النتائج إلي أن إحلال 10% من الرماد المتطاير من وزن الاسمنت تزيد مقاومة الضغط بنسبة 17% وإحلال نسبة 20% من غبار السليكا من وزن الاسمنت تزيد مقاومة الشد بنسبة 17% وذلك للمرحلة الاولي. وإحلال نسبة 20% من الرماد المتطاير و10% من الميتاكولين من وزن الأسمنت تزيد قيمة اجهاد الضغط بنسبة 13.6% وإحلال نسبة 5%من غبار السليكا و5% من الميتاكولين من وزن الاسمنت تزيد قيمة إجهاد الشد بنسبة 3.1% وذلك للمرحلة الثانيه. وكذلك إحلال نسبة 5% من الميتاكولين من و 15% من الرماد المتطاير من و20%من غبار السليكا من وزن الاسمنت تزيد قيمة مقاومة الضغط بنسبة 8.2% و إحلال نسبة 10% من الميتاكولين و 20% من الرماد المتطاير و10%من غبار السليكا من وزن الاسمنت تزيد قيمة مقاومة الضغط بنسبة 4.9% وذلك للمرحلة الثالثه

***Abstract*—Green concrete is a concept of thinking environment in concrete considering every aspect from row materials manufacture over mixture design to structural design. It has nothing to do with color.**

The use of various types of recycled waste materials as raw material in cement production is important recent developmental aspect in the field of cement and concrete science is, as well as the use of these materials as aggregate in the production of various types of concrete. Cement and concrete production can consume a substantial percentage of the total generated waste materials, which can alleviate the acute environmental impact of these materials and also partly help to achieve the much needed sustainability in cement and concrete production. The use of waste materials as aggregate in concrete can consume vast amounts of them taking into account the scale of concrete production all over the world as well as the percentage of aggregate in the overall concrete volume

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Reham M. Ibrahim, B.Sc.Civil Engineering, Structural Dept.Faculty of engineering,Mansoura University Egypt, Email: eng_reham49@yahoo.com

Mohamed Y. Elshikh, Associate Professor, StructuralDept.,Faculty of engineering,Mansoura University, Egypt.

Abd EL-A zeez EL-Hlawany, Associate Professor, StructuralDept.Faculty of engineering,Mansoura University, Egypt.

I. INTRODUCTION

USING of Natural Egyptian Materials (NEM) as supplementary cementations material such , silica fume , fly ash , metakaoline....act, has become common lately years in the production of concretebecause Environmental issues such as climate change andassociated global warming, depletion of natural resources and biodiversity, water and soil pollutions, generation of huge amounts of waste materials and their disposal are some of the great challenges faced by present-day civilization Each of these issues creates serious crisis to the future development of humankind if they are not tackled properly..

II. The Basic Concept And Method Of NEM

Natural Egyptian Materials (NEM) is a methodology for evaluating the environmental loads of processes and products during their life cycle; from cradle-to-grave [The residential sector consumes huge amounts of energy all over the world. The energy used in the construction sector comprises direct use at the construction site and indirect energy used in the manufacture of the building materials.

III. Effect Of Green Concrete In Building

☒ Concrete creates sustainable site.
☒ Concrete enhances energy performance.
☒ Concrete contains recycled materials.
☒ Concrete is manufactured locally.
☒ Concrete builds durable structures.

IV. Environmental Impact Of Concrete

Portland cement, the principal hydraulic binder used in modern concrete, is the product of an industry that is not only energy-intensive, but is also responsible for large emissions of carbon dioxide (CO2)—a greenhouse gas. Typically, ordinary concrete contains about 12% cement, 8% mixing water and 80% aggregate by mass. This means that, in addition to the 1.6 billion tons (1.5 billion tones) of cement used worldwide, the concrete industry is consuming 10 billion tons (9 billion tones) of sand and rock, and 1 billion tons (900 million tons) of mixing water annually.5. In total,the concrete industry, which uses 12.6 billion tons

(11.4 billion Tones) of raw materials each year, is the largest user of natural resources in the world. Mining, processing, and transporting huge quantities of aggregate, in addition to about 3 billion tons (2.7 billion tones) of the raw materials needed every year for cement manufacturing, consume considerable energy and adversely affect the ecology of the planet

V. CO2 Emitted Into Atmosphere At The Various Steps Of A Building Life Cycle

Green concrete is type of concrete which resemble the conventional concrete but the production or usage of such concrete requires minimum amount of energy and causes least harm to the environment.

These activities also consume huge amounts of most nonenergy- related resources, create high volumes of waste and are responsible for enormous pollution in the atmosphere, soil and water. The uses of energy and the emission of CO2 take place at various steps, such as raw material extractions, transportation, manufacture, demolition, service life and waste processing. Table 1.1 shows a typical example of calculation of the emitted amount of CO2 into the atmosphere at the various steps of a building life cycle (BIS 2010).

TABLE 1
CO2 EMITTED INTO ATMOSPHERE AT THE VARIOUS STEPS OF A BUILDING LIFE CYCLE (BIS 2010)

Steps	**Steps Amount of CO2 emitted Quantity (Mt)**	**%**
Design	1.3	0.5
Manufacture	45.2	15
Distribution	2.8	1
Operation on-site	2.6	1
In use	246.4	83
Refurbishment/demolition	1.3	0.4
Total	298.4	100

VI. Reduction of Co2 Emission

The potential environmental benefit to society of being able to build with green concrete is huge. It is realistic to assume the technology can be developed which can halve the co2 emission related to concrete production. It may be possible to use residual products from other industries in concrete production while still maintaining a high concrete quality. During the last few decades society has become aware of the deposit problems connected with residual products and demands, restriction and taxes have been important.

VII. Objectives

The aim of this research is to study the effect of new combinations of supplementary cementing materials (metakaoline, silica fume, and fly ash) as a partial replacement of cement on the strength and durability of high performance concrete..

VIII. Scope of the Investigation

This research has been split into sub-stages as listed below

- Stage I studies the effect of one type replacement of silica fume, fly ash, metakaoline. The tests included in this stage were compressive and tensile strength tests at ages 7 and 28 days. The total number of mixes in this stage was thirteen mixes.

- Stage II studies the effect of two type replacement of silica fume, fly ash, and metakaoline. The tests included in this stage were compressive and tensile strength tests at ages 7 and 28 days. The total number of mixes in this stage was nine.

- Stage III studies the effect of three type replacement of silica fume, fly ash, and metakaoline. The tests included in this stage were compressive and tensile strength tests at ages 7 and 28 days. The total number of mixes in this stage was eight.

IX. Experimental Program Materials

The materials used in this study were Ordinary Portland cement, Silica fume, Fly ash, Metakaoline, sand, gravel, super- plasticizer with market name of Sika-viscocrete5920 and mixing water. The materials were brought from different locations across country. Ordinary Portland cement (OPC) was obtained from Suez factory, while Silica fume powder was obtained from Sika Company. Fly ash powder was obtained from ASH.TECH. Company. Metakaoline powder was obtained from Middle East Mining Investments Company. Sand was obtained from EL-Abbasa quarries. While gravel obtained from Abu-Zaabal quarries the description of each of the material is described in the following sections

X. Cement

Cement used in this study was the Ordinary Portland Cement produced by Suez factory of specific surface area 365 m²/kg as obtained from the Blaine test was used. The cement was kept in an airtight container and stored in the humidity controlled room to prevent cement from being exposed to moisture. The physical and chemical properties of this material were shown in Tables 2 and 3

TABLE 2
PHYSICAL PROPERTIES OF OPC

ESS limits	Test results	Property
>2750	2900	Specific surface area (cm²/gm.)
----	25	Standard consistency (%)
<10	1.5	Le chat elite (mm)
>0.45	75	Initial setting time (min)
<10	4.00	Final setting time (hour)
>27	30	Compressive strength at 7 days (N/ mm²)
>36	38	Compressive strength at 28 days (N/ mm²)

TABLE 3
CHEMICAL ANALYSIS OF OPC

ESS limits	Value (%)	Chemical component
----	60.10	Cao
----	3.00	Fe2O3
----	0.40	Na2O
----	0.18	K2O
<4	2.00	MgO
----	5.00	Al2O3
<3.5	2.90	SO3
----	22.40	SiO2
.01%	0.00	CI
<4	1.4	Loss On Ignition
.066-1.02	0.98	Lime Saturation Factor
<1.50	0.90	Insoluble residue

XI. Silica Fume

It is by-product material resulting from the industry of Ferro-silicon alloys. The physical and chemical properties are given in Tables 4 and 5.

TABLE 4
PHYSICAL PROPERTIES OF SILICA FUME

Property	Test results
Specific surface area (m²/gm.)	16.70
Specific gravity	2.10
Color	Light grey
Texture	Very fine powder with average particle size around 0.1 micrometers.

TABLE 5
CHEMICAL PROPERTIES OF SILICA FUME

property Chemical component	Value (%)
SiO2	95
Fe2O3	0.5
Al2O3	0.2
Cao	0.2
PH value	6.5
Loss On Ignition	0.5

XII. Fly ash

Fly ash used in this study was obtained from ASH.TECH.Company in Egypt. The physical and chemical properties are given in Tables 6 and 7

TABLE 6
PHYSICAL PROPERTIES OF FLY ASH

property	Test results
Specific surface area (m²/gm.)	13.1
Specific gravity	2.13
Color	Grey
Texture	Very fine powder with average particle size around 0.1 micrometers.

TABLE 7
CHEMICAL PROPERTIES OF FLY ASH

Property Chemical component	Value (%)
SiO2	58.55
Fe2O3	4.33
Al2O3	28.20
Cao	2.23
Mgo	0.32
So3	0.07
Na2O	0.58
K2o	1.26
Loss On Ignition	4.17

XIII. Metakaoline

Metakaoline is a highly reactive pozzolanic admixture and has achieved significant potential for the development of concrete composites such as High Strength High Performance Concrete (HSHPC) and self-compacting concrete (SCC), if appropriately designed. However, for obtaining the required performance in any of these concrete composites, metakaoline should be properly proportioned so that the resulting concrete would satisfy both the strength and performance criteria requirements of the structure. It was produced by incinerating the kaolin powder at 750ºc for two hours in electrical oven, as shown in photo to that end, the kaolin powder was stored in the oven before heating up, and after the incineration period left to completely cool down. The physical and chemical properties are given in Table 8 and 9

TABLE 8
PHYSICAL PROPERTIES OF METAKAOLINE

property	Test results
Specific surface area (m^2/gm.)	12
Specific gravity	2.5
Color	Grey
Texture	Very fine powder with average particle size around 0.1 micrometers.

TABLE 9
CHEMICAL PROPERTIES OF METAKAOLINE

property Chemical component	Value (%)
SiO2	53.5
Fe2O3	4.33
Al2O3	30
Cao	0.78
Mgo	0.16
So3	---
Na2O	0.26
K2o	0.62
Loss On Ignition	0.98

XIV. WATER

Water is needed for the hydration of cement and to provide workability during mixing and for placing. There is no much limitation for water except that the water must not be severely contaminated. In this study, normal tap water was used. The chemical analysis of the used water and its allowable limits are given in Table 10

Component	Test result	Max.allowable value
PH value	7.25	>7.0
Total dissolved solids	610	Not more than 2000ppm
Ca	75	Not more than 200ppm
Mg	125	Not more than 150ppm
Ci	150	Not more than 500ppm
SO3	180	Not more than 300ppm
Organic materials	60	Not more than 100ppm

XV. MIX PROPORTIONS AND MIXTURE DETAILS

The number of mixes in the research is 30 concrete mixes, which divided into three phases, all mixes, were designed to have a constant water/powder ratio 0.45. Super plasticizer was used to increase the workability required for mixing and casting. The mixing processes were carried out using a laboratory mixer of 0.05m³ capacities. The aggregates and opc/powder were mixed dry for one minute, then half of the water added and mixing continued for another minute. The mix was left covered for eight minutes to allow for water absorption of aggregate. The remaining water with super plasticizer was then added and mixed for two minutes. Finally, hand mixing was performed to ensure that the concrete is completed homogeneous. Mixing process was carried out at the laboratory of properties and testing of materials department at Faculty of Engineering Mansoura University.

The designation of theses mixes is experimental work implemented into molds. The 150 *150*150 mm standard cubes and150*300 cylinders for all type of concrete specimens. of 150mm diam. and 300mm long, and 3 standard cylinders. Curing started after the specimens were molded of 24 hours, and the specimens were tested at 7 and 28 days. Tables 11, 12 and 13 show the quantities of concrete mix used in the experimental work

Table 11 Mix proportions (per 1m³of concrete)used in this stage

Phase	Mix type	w/c	Cement (kg/m³)	Silica Fume SF(%)	Fly ash FA(%)	Metakaoline M(%)	Water (kg/m³)	Sand (kg/m³)	Gravel (kg/m³)	Supper plasticizer (%)
	C	0.4	450	-	-	-	180	528	1200	1.5
Phase I	SF5	0.4	427.5	5%	-	-	180	518.8	1200	1.5
	SF10	0.4	405	10%	-	-	180	509.5	1200	1.5
	SF15	0.4	382.5	15%	-	-	180	500.2	1200	1.5
	SF20	0.4	360	20%	-	-	180	490.9	1200	1.5
Phase II	FA5	0.4	427.5	-	5%	-	180	519.2	1200	1.5
	FA10	0.4	405	-	10%	-	180	510.3	1200	1.5
	FA15	0.4	382.5	-	15%	-	180	501.4	1200	1.5
	FA20	0.4	360	-	20%	-	180	492.5	1200	1.5
Phase III	M5	0.4	427.5	-	-	5%	180	523.2	1200	1.5
	M10	0.4	405	-	-	10%	180	518.4	1200	1.5
	M15	0.4	382.5	-	-	15%	180	513.6	1200	1.5
	M20	0.4	360	-	-	20%	180	508.8	1200	1.5

Table 12 Mix proportions (per 1m³of concrete)used in this stage

Phase	Mix type	w/c	Cement (kg/m³)	Silica Fume SF(%)	Fly ash FA(%)	Metakaoline M(%)	Water (kg/m³)	Sand (kg/m³)	Gravel (kg/m³)	Supper plasticizer (%)
Phase I	SF5+FA10	0.4	382.5	5%	10%	-	180	501	1200	1.5
	SF10+FA20	0.4	315	10%	20%	-	180	473.9	1200	1.5
	SF10+FA10	0.4	360	10%	10%	-	180	491.7	1200	1.5
Phase II	SF5+M5	0.4	405	5%	-	5%	180	514	1200	1.5
	SF15+M10	0.4	337.5	15%	-	10%	180	490.6	1200	1.5
	SF20+M10	0.4	315	20%	-	10%	180	481.3	1200	1.5
Phase III	FA5+M10	0.4	382.5	-	5%	10%	180	509.5	1200	1.5
	FA10+M5	0.4	382.5	-	10%	5%	180	505.5	1200	1.5
	FA20+M10	0.4	315	-	20%	10%	180	482.8	1200	1.5

Table 13 Mix proportions (per 1m³of concrete)used in this stage

Phase	Mix type	w/c	Cement (kg/m³)	Silica Fume SF(%)	Fly ash FA(%)	Metakaoline M(%)	Water (kg/m³)	Sand (kg/m³)	Gravel (kg/m³)	Supper plasticizer (%)
Phase I	SF5+FA10+M5	0.4	360	5%	10%	5%	180	496.2	1200	1.5
	SF10+FA20+M10	0.4	270	10%	20%	10%	180	464.3	1200	1.5
	SF5+FA10+M15	0.4	315	5%	10%	15%	180	486.5	1200	1.5
	SF15+FA5+M10	0.4	315	15%	5%	10%	180	481.7	1200	1.5
	SF20+FA10+M15	0.4	247.5	20%	10%	15%	180	458.7	1200	1.5
	SF10+FA15+M5	0.4	315	10%	15%	5%	180	478	1200	1.5
	SF5+FA10+M10	0.4	337.5	5%	10%	10%	180	491.3	1200	1.5
	SF5+FA15+M10	0.4	315	5%	15%	10%	180	482.2	1200	1.5

XVI. RESULTS AND DISCUSSIONS

Stage I.Effect of Using one type replacement of silica fume, fly ash, metakaoline.

The aim of this stage was to come out with the efficiency of using one type replacement of silica fume, fly ash, metakaoline. The tests included in this stage were compressive and tensile strength tests at ages 28 day. The total number of mixes in this stage was thirteen. Figures (1-1) and (1-2) show the test results for all mixes

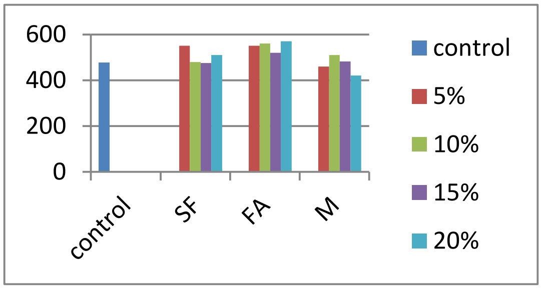

Figure (1-1) compressive strength of stage I

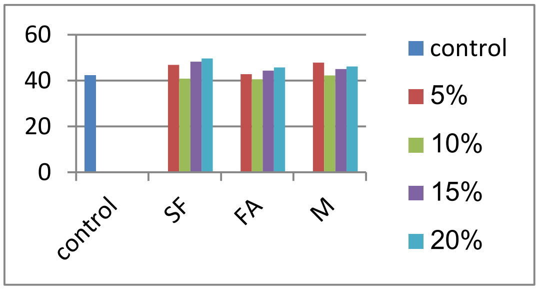

Figure (1-2) Tensile Strength of stage I

Stage II. Effect of Using of two type replacement of silica fume, fly ash, metakaoline.

The aim of this stage was to come out with the efficiency of using two type replacement of silica fume, fly ash, metakaoline. The tests included in this stage were compressive and tensile strength tests at ages 28 day. The total number of mixes in this stage was nine. Figures (2-1) and (2-2) show the test results for all mixes

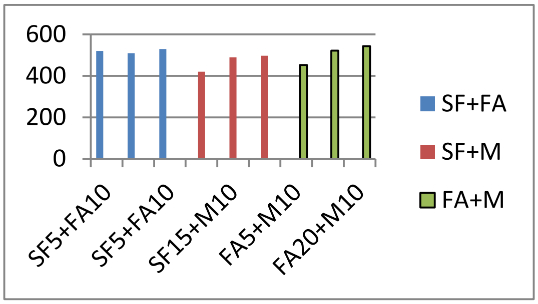

Figure (2-1) compressive strength of stage II

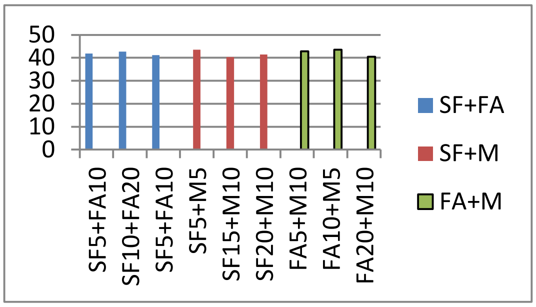

Figure (2-2) Tensile Strength of stage II

Stage III.Effect of Using of three type replacement of silica fume, fly ash, metakaoline.

The aim of this stage was to come out with the efficiency of using three type replacement of silica fume, fly ash, metakaoline. The tests included in this stage were compressive and tensile strength tests at ages 28 day. The total number of mixes in this stage was eight. Figures (3-1) and (2-2) show the test results for all mixes

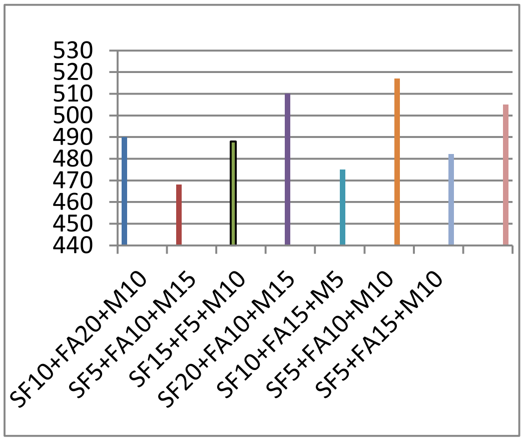

Figure (3-1) compressive strength of stage III

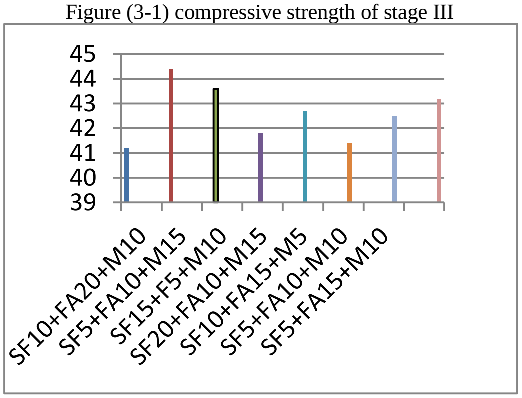

Figure (3-2) Tensile Strength of stage III

XVII. SUMMARY AND CONCLUSIONS

The development of technologies for environmental protection contributes to save and preserve natural resources. Recently, both government and private sectors have accepted the view that rational utilization of non-renewable resources must be achieved.

Good NEM activation improves its properties when adding at concrete.

NEM addition increases compressive strength. As well as mechanical and durability performance of concrete this makes it favorable to be used in control mix.

The results obtained by Green Concrete show that it is possible to produce green concrete types where the properties such as durability, workmanship and mechanical % of replacement silica fume, fly ash and metakaoline

Properties are just as good as for ordinary concrete.

10% of replacement of fly ash improves the physical and mechanical properties of concrete

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