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Use the polymer concrete as a substitute for ordinary concrete by improving of acoustic and thermal insulation with suitable cost

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Abstract

The purpose of this study is to examine the effect of adding novolac resin by different volumetric percentages to concert as a light weight aggregate In addition to the economic feasibility of the use of these concrete in the field of build and construction .they investigated tht the compression strength, thermal conductivity, acoustic insulation and densities. The results showed ultimate compression strength and acoustic insulation by melting novolac and added to the cement and sand as a polymer concrete in the hot state (by melting novoac >90c).However added novolac resin as aggregate in the cold state to the concrete increase thermal conductivity and increasing compression strength and acoustic insulation .This results gained by chemical interaction of novolac and cement.

Keywords: thermal insulation, acoustic insulation, novolac aggregate concrete, Noor Al_Huda disc, compressive strength, density.

استخدام الخرسانة البوليمرية كبديل عن الخرسانة العادية بتحسين العزل الصوتي والحراري وبكلفة مناسبة

الخلاصة:

الغرض من هذا البحث هو دراسة تأثير اضافة نسب حجمية مختلفة من راتنج النوفولاك الى الخرسانة كركام خفيف الوزن بالإضافة الى الجدوى الاقتصادية من استخدام هذه الخرسانة في مجال البناء والتشييد. تم فحص مقاومة الانضغاط والموصلية الحرارية والعزل الصوتي والكثافة للنماذج المعدة في البحث وبالنسب المؤشرة ازاء كل منها. النتائج بينت ان اقصى مقاومة انضغاط وعزل صوتي تم الحصول عليها في حالة مزج الراتنج النوفولاك مع السمنت والرمل في الحالة الساخنة بدرجة حرارة ما فوق ٩٠ درجة سيليلوزية، ومع ذلك فأن أضافة راتنج نوفولاك في الحالة الباردة كركام ادى إلى زيادة الموصلية الحرارية وزيادة قوة الضغط والعزل الصوتي. هذه النتائج المتحصلة نتيجة التفاعل الكيميائي للنوفولاك مع الأسمنت.

الكلمات الاسترشادية:العزل الحراري, العزل الصوتي, خرسانة ذات ركام النوفولاك, قرص نور الهدى, مقاومة الانضغاط، الكثافة.

Introduction:

With the rising energy costs and increasing awareness on the effects of global warming, the need for energy efficient design and construction has become increasingly urgent. Because of the aforementioned reasons, the measurement of thermal conductivity of lightweight and normal-weight density concretes is very important. There are many methods used to determine thermal conductivity like hot guarded plate, hot wire method and the transient plane source method. Each necessitates specimens of particular material and geometry. . Thermal conductivity is a physical property which expresses the ability of the material to conduct heat, it is a characteristic property of the material and its value may depend on density, moisture content, pore structure, shape of the solid particle, temperature and composition of the material, type of material and type of entrained gas in the material. At normal temperatures the thermal conductivity of solids covers a range of magnitude, from 0.02 W/m.°C for the best insulates such as urethane, rigid foam to 2300 W/m.°C for the best conductors such as diamond(1). It is possible to express thermal conductivity of a material by the following formula (1)(2):

$$K = \frac{Q.d}{t1 - t2.S.\tau} \quad \ldots\ldots (1)$$

Where Q is heat flow (J), (t1 – t2) is temperature between two points, in temperature field (°C), *d is* distance (m), *S* is area (m^2) and τ is time (sec).

As the construction industry is considered to be one of the fastest growing industries, decreasing the heat loss in buildings by enhance its thermal insulation properties is important, as it would enable energy efficient buildings and improve environmental sustainability. In addition, the usage of industrial waste would be an added advantage. Ng and Low [3] discovered that sandwiched newspaper, which could be used as the wall envelope for energy efficient building construction, has a significant impact on the thermal conductivity performance of aerated lightweight concrete panels with a reduction of thermal conductivity of up to 22% compared to the control panels.

Experimental Program

Materials

- **Cement**

Ordinary Portland cement (type I) manufactured in Iraq with trade mark of (Tassloga) has been used throughout this investigation. It has been stored in airtight plastic containers to avoid exposure to atmospheric conditions. Its chemical composition and physical properties are given in Tables (3) &(4) respectively. The test results show that the cement conforms to the provisions of Iraq specification No.(5)-1984(4).

- **Fine Aggregate**

Natural sand has been used from (Al-Soddor source), as a fine aggregate after it has been sieved by sieve size (4.75 mm).The grading of fine aggregate was as show in Table (5).It was conformed to Iraq specification No.(45)-1984 [5] where the gradation lies in zone (3) . The specific gravity, bulk density and absorption of the fine aggregate were (2.65, 1650, 2.2%).

- **Novolac resin(coarse aggregate)**

Novolac solid resin has been used from al_sawarry company, as a coarse aggregate after it has been sieving analysis. It was conformed to Iraq specification No.(45)-1984 [5].

Mixes ,Mixing and Preparation of Specimen

After conducted many trial mixes to select the suitable mix, A 100 mm cubes, circular steel disc molds are used to prepare the test specimen of this study. final mix. had the following constituents for each type of novolac used:-

1. Normal concrete mix C_N (1/6.4) cement/aggregate ratio by volume with w/c ratio= 0.45 (3.6 normal coarse aggregate and 2.8sand) .

2. Melting novolac with sand and cement NS_m (40%cement, 40% novolac,10%sand) by volume. This mix was prepared by mixing cement and sand and added to novolac melting by heating novolac until melting point (approximate> 90 C°)

3. Novolac with cement NC_w(cement 35%, novolac 35% and water 30%) by volume . we mixed the novolac with cement homogenously and added water until reaching the suitable workability of mixture. was prepared by mixing the novolac with cement and sand homogenously volumetric ratio as shown above, then added water until reaching the suitable workability for mixture.

Experimental Tests

- **Compressive Strength Test**

The compressive strength was determined from cubes of (100*100) mm specimen's according to B.S.1881[6] .

- **Saturated surface dry density (air dry density)**

The test is performed in accordance with **ASTM C567-05a** (7) using cubes samples of size (100 * 100) mm, and taking the average result of three samples 28 days for each mix.

- **Thermal Conductivity**

Thermal conductivity, k, is the property of a material that indicates its ability to conduct heat. Conduction will take place if there exists a temperature gradient in a solid (or stationary fluid) medium. Energy is transferred from more energetic to less energetic molecules when neighboring molecules collide. Conductive heat flow occurs in direction of the decreasing temperature because higher temperature is associated with higher molecular energy. Noor Al Huda disc method was used to measure thermal conductivity in this research (Patented standardization and quality control device of Iraq to the 2016), it is commonly used to measure thermal conductivity of construction materials like concrete. The apparatus consists of two parts. The steam boiler and steam chamber. The steam chamber part consists of two brass discs and steam chamber. One of brass disc is fixed and other is moving. Each of them with the same thickness and diameter and each of them contain one holes for inserting thermometer to measure T1 and T2. Also steam chamber consists of two holes, upper and lower, from two sides are provided for inflowing and out flowing of steam.

Acoustic insulation test

Acoustic insulation was measured using the locally made acoustic insulation measurement device according to ASTM E-336 (available in University of Technology/ Materials Engineering Department). It consists of four parts: wave generator device, device to amplify the wave, laud speaker and wave receiving device. The test started when the wave was generated by the wave generator device and then amplified. The wave then transferred to a loud speaker attached with a wooden box. The specimen was placed in the middle of this box, then the box was closed and then the wave at different frequencies (about 15 frequencies) was applied. For every frequency, the wave was taken from the receiving wave device. This test must be done in a very static medium and without any movement in the whole place, because this may lead to an imbalance in the obtained results. The sample used in this test has dimensions ($240 \times 240 \times 5\ mm^3$).

Results And Discussion

Compressive strength

Table (1) and Fig. (2) illustrate the results of compressive strength of all types of mixes. Although the issue of compressive strength is not important in the insulating panels, but the important issue in the production of lightweight concrete is density to achieve a suitable thermal and acoustic insulation. The compressive strength of lightweight concrete increases with the increase dry density. The cement content also has a significant role in compressive strength because concrete mix with high cement content exhibit higher compressive strength than concrete mix. with low cement content because increase cement paste around aggregate particles leads to improve cohesive strength and bond between aggregate particles and cement paste, therefore the value of compressive strength of (CN) is 25 MPa, but for (NCw, NCsw) is (2.6, 2.2) MPa respectively this decrease in compressive strength due to lightweight and weak particle of novolac aggregate additional to low strength of it compared with normal aggregate used in reference concrete mix (CN).

Density test results

Table (1) and Fig. (1) illustrate the results of density of conducting mixes, generally there is decrease in density of all mixes than reference concrete (CN) due to lightweight novolac aggregate than normal aggregate. The percentage of decrease in S.S.D density of (NSm, NCw, NCsw) as compared with S.S.D density of reference concrete mix (CN) are (28.3%, 32.5% and 35.8%) respectively, the using of novolac aggregate instead of normal aggregate has a great impact on this decrease.

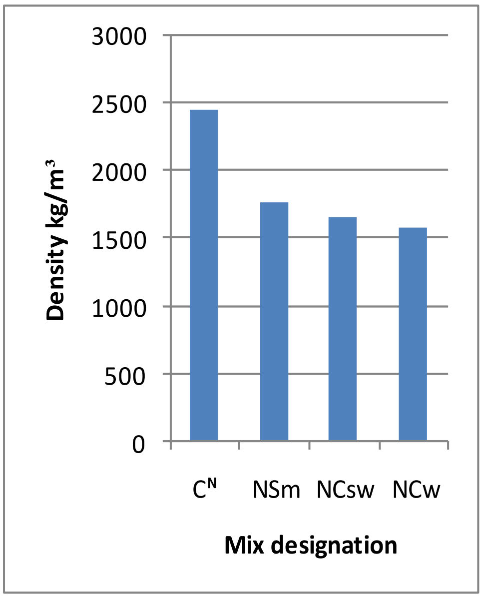

Fig.(1) density test result of mixes of mixes

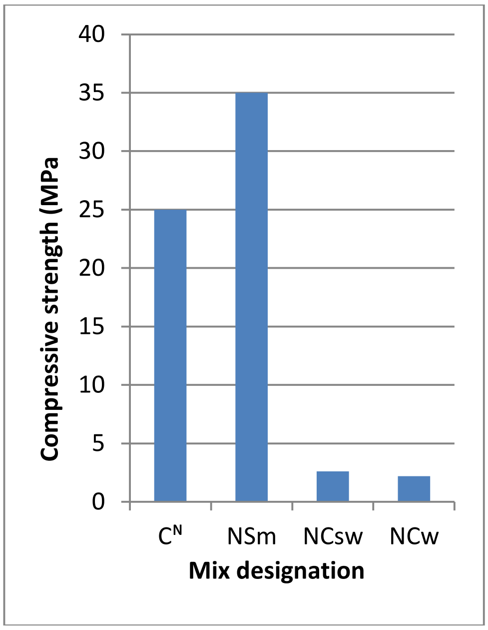

Fig.(2) compressive strength of mixes

Thermal conductivity test result

Thermal conductivity test was conducted for 12 discs sample and the average of each three tests results for each mix at 28 days are shown in Table (1). From Fig.(3), it is observed that the thermal conductivity values of all mixes decreases proportionately to the density. The thermal conductivity values for S.S.D density (2455 and 1575 kg/m^3) is (0.3, 0.212 W/m.°C) respectively for normal aggregate and novolac and cement with sand mixes (C_N, NC_{sw}). This has translate to 29.3% reduction on thermal conductivity for density 1575 kg/m^3 for(NCsw) compared to reference concrete mix of 2455 kg/m^3 density, regardless type of aggregate used whether normal aggregate or novolac aggregate. Similar trend of thermal conductivity reduction was observed for other two mixes. For range density of (1758, 1655 kg/m3)thermal conductivity was ranged (0.226- 0.258 W/m.°C). The reduction in thermal conductivity for this range of density compared with reference disc of density 2455 kg/m3 with thermal conductivity is equal to 0.3W/m.°C not only due to the reduced density, but also for using porous aggregate with density and specific gravity lower than normal aggregate.

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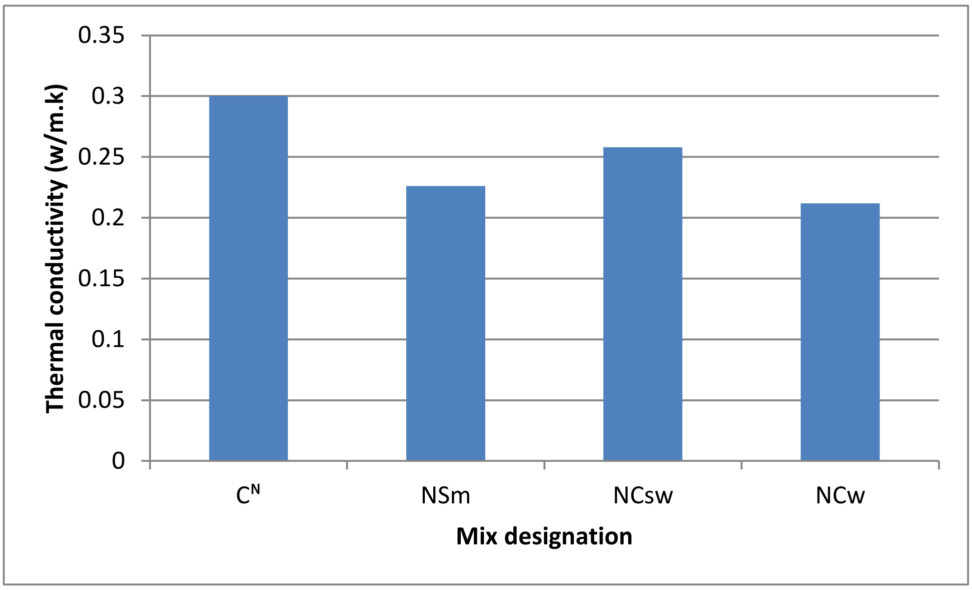

Fig.(3) Thermal conductivity test result of mixes

Acoustic insulation test

The main parameters in the determination of the acoustic insulation properties are sound level, equivalent sound absorption area and sound absorption coefficient. Figures (4) show the experimental results obtained for all mixes. The (NSm) mix revealed higher acoustic insulation properties compared to the other mixes. The maximum amount of acoustic insulation was shown for (NSm) at the frequency (20000 Hz). This may be due to all natural of novolac aggregate mix after melting which make it have good acoustic insulation properties.

A simplified study of economic cost of using polymeric concrete

The objective of using the novolac material was to produce concrete with good thermal and sound insulation properties. After the preparing of several mixtures find that the mixture (**NS$_m$**) is the best between the mixtures in terms of mechanical properties, thermal and acoustic properties where the compressive strength is about 35 (mpa) thermal conductivity 0.226 (W/m.°C) and the question here how much the price per cubic meter of this mixture for use as a new building material**?**

Table (2) shows the price per cubic meter of ordinary concrete and the price of one cubic meter of this new concrete and through the results, they noted decrease of weight about 28% while the drop of price per cubic meter of this concrete to about 40% on the other hand the compressive strength is (28%) higher than conventional concrete. Based on the experimental program results, the following concluded it is possible to produce concrete mix by using novolac resin as a new building material for insulation application.

Conclusion

1- Good thermal insulation in sample consists of (crushed novolac resin and cement with existence heat as assistant factor) is best compared with other samples.
2- Good acoustic insulation in sample consists of (crushed novolac resin, sand, cement and water) compared with normal concrete.
3- The compressive strength in sample consists of (crushed novolac resin melting novolac with sand) 35 MPa and density 1758 kg/m^3.
4- The drop of price per cubic meter of polymer concrete to about 40% than conventional concrete and the compressive strength is (28%) higher than conventional concrete.

Recommendations

studying the replacement of cement material with another substance within the used building materials.

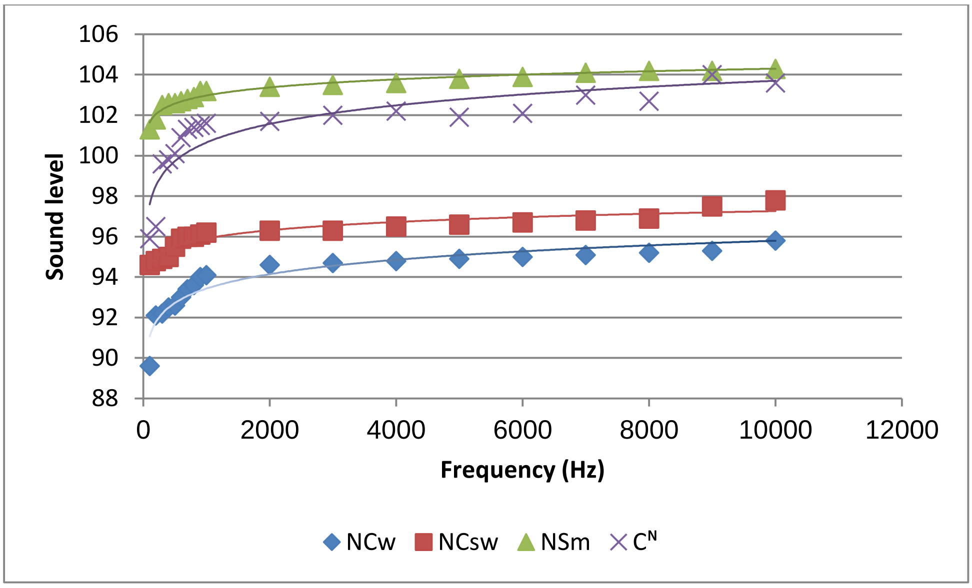

Fig. (4) acoustic insulation test result of mixes

Table (1) results of the compressive strength saturated surface dry (S.S.D) density and thermal conductivity for all mixes

Set No.	Mix details	Mix Designation	Compressive strength (Mpa)	S.S.D density (Kg/m^3)	Thermal conductivity (W/m.°C)
١	**Normal aggregate concrete**	**C_N**	**25**	**2455**	**0.3**
٢	**melting novolac with sand**	**NS_m**	**35**	**1758**	**0.226**
٣	**novolac with cement**	**NC_w**	**2.2**	**1655**	**0.258**
٤	**novolac and cement with sand**	**NC_{sw}**	**٢,٦**	**1575**	**0.212**

Table (2) result of study of economic cost of using polymeric concrete as a compared with convectional concrete.

Set No.	Mix details	Mix Designation	Weight of cubic meter (kg)	Reduction in weight (%)	Compressive strength (Mpa)	Increment of compressive strength (%)	Cost of cubic meter in dinar	R
١	**Normal aggregate concrete**	**C_N**	**2455**	**0**	**25**	**0**	**300000**	
٢	**melting novolac with sand concrete**	**NS_m**	**1758**	**28**	**35**	**28**	**180000**	

Table (3) Chemical oxide analysis, weight %, for cement used.

Oxide	Content %	Limit of Iraq specification No.(5) _ 1984[9]
CaO	52.21	—
SiO_2	20.18	—
Al_2O_3	5.00	—
Fe_2O_3	3.60	—
MgO	2.31	<5
SO_3	1.44	< 2.8
Na2O	0.28	—
K_2O	0.51	—
Insoluble Residue I.R	1.11	<1.5
Loss on ignition L.O.I	3.29	<4.0
Lime Saturation Factor ,L.S.F.	0.94	0.66-1.02

Table (4) Physical properties of cement (Type I).

Physical properties	Test results	Limit of Iraq specification No.(5) _ 1984[9]
Specific surface area (Blaine method), m^2/kg	483	≥230
Setting time (Vicate apparatus), Initial setting time, hrs: min	2.50 4.30	≥45 min. ≤ 10 hrs

Final setting time, hrs: min		
Soundness (Auto Clave) method, %	0.25	≤0.8

Table (5) :Grading & soluble material for fine aggregate .

Sieve size (mm)	% Passing Sand	Limits of Iraqi specification No.45/1984[10] (Cumulative passing % zone 3)
9.5	100	100
4.75	92.0	90-100
2.36	82.8	85-100
1.18	76.1	75-100
0.6	63.4	60-79
0.3	35.9	12-40
0.15	9.8	0-10
Fine Material%	4.6%	≤5%
Organic Material%	0.69%	≤3%

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