THE EFFECT OF USING RECYCLED AGGREGATES ON CONCRETE DURABILITY INDICATORS

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ABSTRACT

The issue of recycling is of great importance globally, as a result of the increase in waste of all kinds that resulted from natural or human disasters, especially construction rubble, which requires large areas of landfill to accommodate it, in addition to the large material burdens resulting from relocation and disposal operations. This industrial development that our world has witnessed has forced... Technicians must search for clear scientific methodologies to benefit from recycling demolition waste so that it is suitable for use in engineering works, which makes it extremely important and an area that helps maintain a clean environment. Preliminary results show the possibility of using recycled aggregates in concrete instead of natural aggregates, but the researchers' greatest concern was the possibility of these recycled aggregates performing for a long time in concrete. Most studies indicate a decrease in resistance values when replacement rates increase, but the study of the durability of these stones in concrete was relatively weak because it required a long time and advanced techniques to probe the structure of concrete after it was exposed to destructive conditions. Hence, it was necessary to study the change in the properties of this concrete with time and to study its durability under the influence of many factors, such as the effect of destructive materials (acids and salts), mechanical resistance, capillary absorption of water, and gas permeability, and to measure the extent of the effect of replacing natural gravel with recycled gravel on its durability properties. The research results show good values for the durability indicators of concrete manufactured using recycled aggregates compared to concrete manufactured from natural aggregates only, as the durability indicators improve up to a 50% replacement rate.

Keywords: recycled aggregate, durability of concrete, concrete proprieties, Acid attack, Salt immersion.

1. Introduction

With the successive and accelerated Urban Development and the praise of new buildings and modern requirements, the problem of disposing of rubble resulting from demolition operations has emerged. it has been noted that there is a large percentage of building rubble (concrete, block, household tiles, etc.) that does not decompose compared to organic waste dissolved by water or air. All this makes thinking about a certain methodology for disposing of these ruins so that they are suitable for use in engineering works extremely important and an auxiliary field for maintaining a clean environment, which prompted many countries of the world to look for certain mechanisms to benefit from these ruins and turn them into materials that can be used instead of being the cause of many problems at various levels.

To keep pace with international research in this field, the researcher studied the possibility of using recycled Pebbles for a long time in the Piton and studied the indicators of the durability of the Piton, and the raw materials used in this research were obtained from one of the demolition licenses granted by the Latakia city council. It was transferred to the Materials Testing Laboratory at Tishreen University, processed manually and automatically and converted into pebbles of suitable sizes used for making Petonic samples with different replacement ratios and then conducting durability tests on these sample.

2. Mechanisms and causes of corrosion and destruction of bitumen:

2.1. internal causes: They are caused by the materials involved in the manufacturing process of bitumen or the presence of contaminated materials such as active silica, clay, or the presence of harmful salts of these components, all of which lead to reactions that destroy bitumen.

2.2. external causes: They are generated by the medium surrounding the Biton such as:

a) The bitumen has been subjected to chemical attack such as exposure to sulfates and chlorides.
b) The resulting bitumen from exposure to sea water corrodes sewage.
c) Being affected by industrial waste, which contains substances that destroy the structure of the bitumen.

2.3. : other reasons:

a) The temperature of groundwater.
b) Fluctuation of the groundwater level.
c) Evaporation on the surface of the bitumen.
d) Oxidation and carbonization.[4]

3. Attack of salts and sulfates:

3.1. salts:

The attack of sulfate salts on the bitumen is one of the most serious problems affecting the durability of the bitumen, as the salts work to ruin the bitumen and corrode it, and its source is either external from surface water or from the soil surrounding the bitumen, or internal from the materials involved in the manufacture of bitumen, from cement, water and additives, and these salts are either calcium sulfate salts, magnesium sulfate salts or sodium sulfate, where they react with calcium hydroxide contained in the cement paste and aqueous tricalcium aluminate, forming gypsum and sulfo-aluminate calcium according to the following equations:

$$Ca(OH)_2+Na_2SO_4\ 1OH_2O \rightarrow CaSO_4\ 2H_2O+2NaOH\ 8H_2O$$

Calcium sulfate reacts with aqueous sulfuric calcium aluminate according to the equation:

$$CaO\ AL_2O_3\ 19H_2O+3(CaSO_4\ 2H_2O)+16H_2O \rightarrow 3CaO\ AL_2O_3\ 3CaSO_4\ 32H_2O+Ca(OH)_2$$

These compounds are larger in size than their size before the reaction, so the interactions with sulfates generate tensile stresses in the interconnected cement paste, so the bitumen attacked by sulfates appears whitish and usually starts with the edges and is followed by increasing cracks in the bitumen leading to its fragility, as the bitumen is exposed to external factors, especially in coastal areas, which between the resistance of bitumen to sulfate and its content of Tri-calcium aluminate C3A, which There is also a relationship in terms of designing a mixture that is more compact and less permeable, and this reduces the penetration of sulfates to the Bitumen. the following figure shows the bitumen exposed to sulfate attack.

Figure (1) shows the attack of salts on the bitumen, which is shown in white:

Figure(1): the attack of salts on the bitumen

2.3. Acids:

If carbon dioxide or sulfur dioxide is present in humid atmospheric conditions or any other acidic vapors, they attack the bitumen, remove part of the cement and form a soft layer that facilitates its removal from the surface of the bitumen. In general, inorganic acids have a severe effect on the bitumen, where they react with free lime, forming chlorides, sulfates and nitrates. The severity of the effect depends on the extent of the solubility of those compounds in water, on the concentration of those acids and on the reaction speed, which increases if the acids are hot. Chlorides are the most substances that destroy the protective layer of rebar, and these chlorides may be present in the bitumen from the moment of formation of the mixture and its source is mixing water or aggregates, etc Chemical reactions in this case are very complex and it was noted in most international specifications reducing the permissible values of the concentration of chlorides in the bitumen and preventing the penetration of chlorides into the bitumen depends mainly on the impermeability of the bitumen and on the thickness of the cap of the rebar.[6]

Researchers Layachi Berredjem, Nourredine Arabi conducted a scientific research entitled "**mechanical properties and durability of bitumen manufactured from recycled bitumen Pebbles**" the experimental method is based on comparing the long – term mechanical resistances of bitumen samples preserved in three types of solutions (drinking water – mineral-free water-very salty water) in order to calculate the durability indicators, namely porosity, permeability and leaching of ammonium nitrate in weak and strong concentrations. Figure (2) shows that the resistance to simple pressure of recycled gravel bitumen is lower than that of natural bitumen, and it is related to the strength of the mechanical ability of the test, and the low resistance is 6.5% for bitumen B3 (natural sand and recycled gravel) and 12% for bitumen B4 (recycled sand and recycled gravel).

Where:

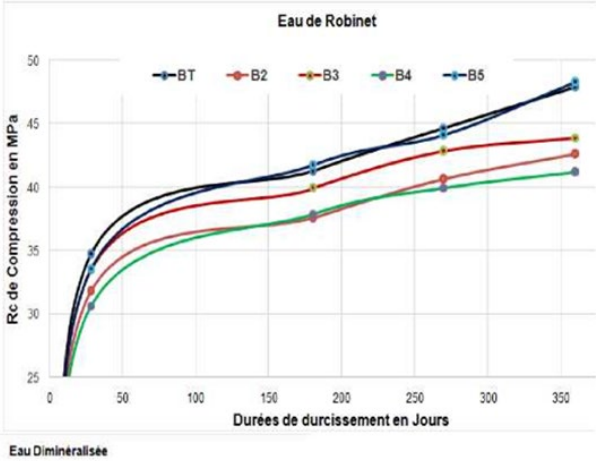
BT: witness bitumen is natural sand and natural pebbles.

B2: consists of recycled sand and natural pebbles.

B3: consists of natural sand and recycled pebbles.

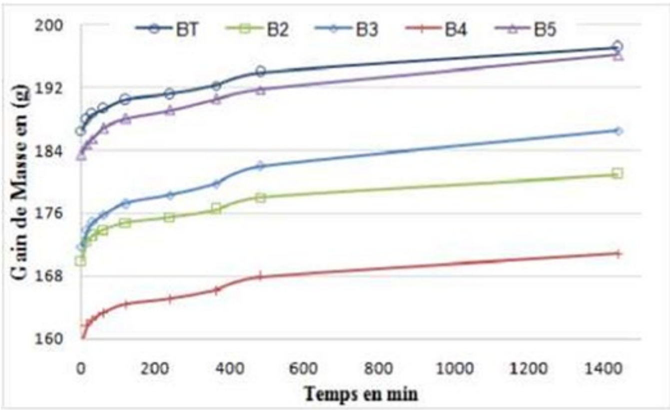
B4: consists of recycled sand and recycled pebbles .

B5: it consists of natural sand, 75% natural gravel and 25% recycled gravel.

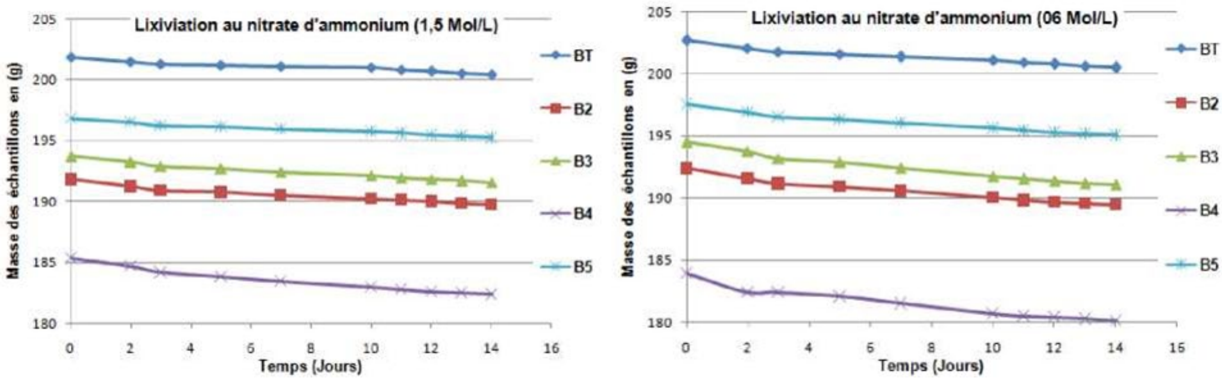


Figure(2): the relationship between the resistance to simple pressure &

Figure (3) shows that the capillary absorption of water for all bitumen samples is similar and Figure (4) shows the mass change since the first hour, especially for recycled sand bitumen bitumen B2 and B4 . This is due to the quality of recycled sand, which contains a porous cement mixture, which includes a large part of the fine shapes After using a jaw crusher, and the absorption for witness or typical BT bitumen samples is similar to the absorption of B5 bitumen, and the highest values observed at the B3 curve consisting of recycled gravel and natural sand are probably due to the high percentage of fine grains in the sand.



Figure(3) the capillary absorption of water according to time



Figure(4):

4.The importance of research and its goals:

This research aims to study the effect of replacing natural stones with recycled stones on the indicators of the durability of bitons, and one of the most important indicators of durability is the effect of acids and salts.

The importance lies in the following main points :

- Studying the possibility of using recycled Pebbles for a long time in the manufacture of bitumen.
- The study of indicators of durability of bitumen manufactured from recycled pebbles under the influence of acid attack and immersion with salts.
- The influence of the use of recycled pebbles on the porosity and permeability properties of the bitumen.

5. Research method and materials used:

The research adopted the experimental methodology regarding the study of rubble and bituminous samples manufactured from recycled pebbles, and the analytical and mathematical methodology to study the change in durability indicators with the proportions of replacing natural pebbles with recycled pebbles.

As for the work steps, they can be divided into the following stages:

- Get the rubble and process it laboratory.
- Characterization of natural pebbles and recycled pebbles .
- Manufacture of laboratory models from bitumen.
- Conducting durability tests on bitumen samples to measure the impact of the durability of bitumen on the change in the replacement ratio.
- Analyze and discuss the results.

For this purpose, we subjected the bituminous samples from all mixtures to an accelerated durability test by immersing the hardened samples after reaching the age of 28 days with a 15% saline solution for 90 days, after which we remove the samples from the solution and study their mechanical properties (resistance to simple pressure – mass loss) and compare it with healthy samples. In addition, we immersed samples after reaching the age of 28 days with a solution of 3% sulfuric acid diluted with water for 90 days, after which we took the samples out of the solution and studied their mechanical properties (resistance to simple pressure – mass loss) and compared it with healthy samples.

5.1 preparations:

The ruins were obtained from one of the demolition licenses granted by the Latakia city council, which included the remains of the demolition of houses and ceramics in addition to the house tiles and blocks. Table No. (1) shows the results of measuring the solid and apparent volumetric weights, the values of the Los Angeles wear coefficient and the values of the maximum water absorption of natural pebbles and recycled pebbles used in the manufacture of bituminous Cube Models[1] :

Table(1):

Sample	Apparent volumetric weight kg/l	Solid volumetric weight kg/l	Los angeles %	Water absorption%
Piton demolition products	1.20	2.33	29.32	7.80
Ceramic demolition products	1.02	2.25	39.28	11
Tile demolition products	1.15	2.29	43.40	12.40

Block demolition product	1.05	2.27	43.20	9.28
Demolition product mix	1.30	2.47	41.60	9
Natural gravel	1.41	2.73	21	3.30
Fine sand	1.49	2.73		
Coarse sand	1.34	2.44		

The sand equivalent values for the two types of sand used were 88% for fine sand originating from nabk and 77% for coarse sand originating from the Northern course of the Kabir River. Ordinary portland cement of Type 1 and class 32.5 from the Tartus plant was used for pouring bitumen. The sodium chloride salt expanded with water by 15% and the use of sulfuric acid expanded with water by 3% were used.

5.2 bitonic mix design:

The bituminous mixture was designed based on the French DREUX-GORISSE method, with the mixtures that were poured with the indication that the symbol R100 symbolizes the mixture in which 100% recycled pebbles were used without natural pebbles, and the symbol R0 indicates a mixture in which 100% natural pebbles were used without recycled pebbles. Five bituminous mixtures were poured with different replacement ratios for natural pebbles(R0,R30,R50,R100) and Figure (5) shows the grain gradient curves of the pebbles used in bituminous mixtures.

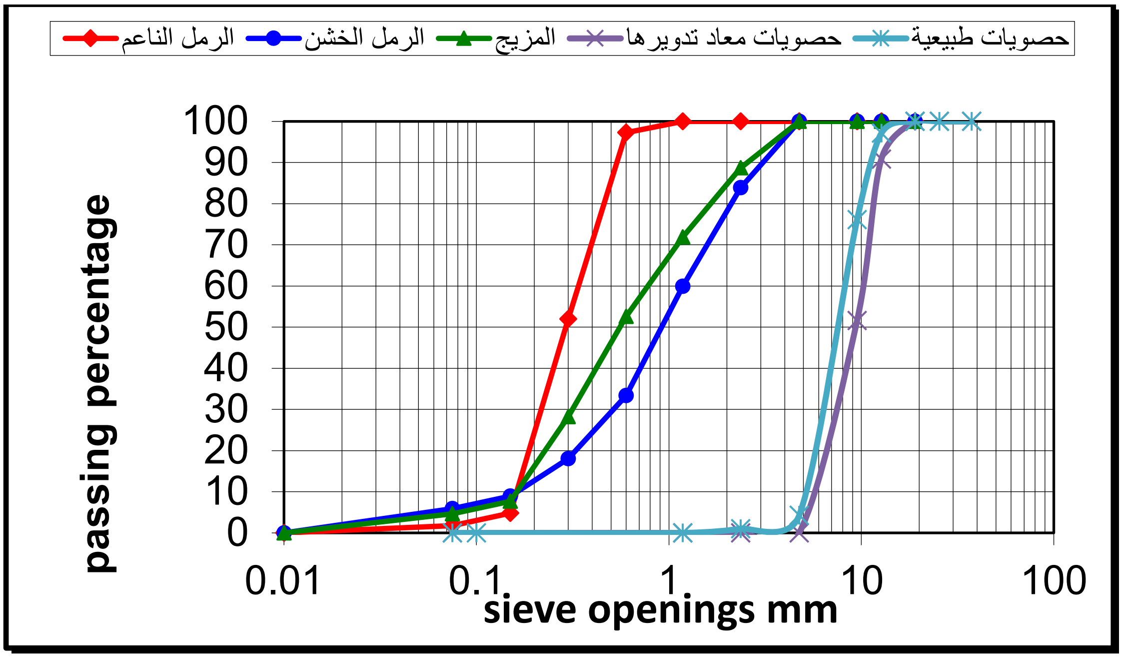


Figure (5) curve of the grain gradient of the tested pebbles

Table (2) shows the results of the design of bituminous mixtures:

Component of gravel mixture				
The mixture	**R0**	**R30**	**R50**	**R100**
Natural coarse grain(kg/m^3)	**1301**	**902.7**	**635**	**0**
Fine sand(kg/m^3)	**184**	**220**	**222**	**226**
Lenticular coarse sand(kg/m^3)	**427**	**509**	**513**	**523**
Cement(kg/m^3)	**350**	**350**	**350**	**350**
Water(kg/m^3)	**166**	**154.2**	**146.9**	**129.1**
Recycled gravel(kg/m^3)	**0**	**306**	**514**	**1047**
Plasticizer(kg/m^3)	**0**	**0**	**0**	**0**

6. Results and discussion:

The following are the most important results achieved after conducting the durability tests, namely measuring the average resistance of bituminous cubes according to the different replacement ratios, in addition to measuring the average resistance of samples after immersion in acids for 90 days by 3% and measuring the average resistance of bituminous cubes after immersion in sodium chloride solution by 15% .Samples of hardened bitumen were represented by cubes with dimensions of 10*10*10cm.

Figure (6) shows the samples of bitumen manufactured from recycled pebbles with different replacement ratios before immersion with acids and after immersion:

Figure(6): samples of bitumen before immersion with acids and after immersion

The number of samples poured from each mixture amounted to fifteen samples and the average values of the test results were adopted in the following result tables.

Table (3): simple pressure test results for bitonic samples (10*10*10 cm)

Reduced resistance after immersion with acids %	Reduced resistance after immersion with salts %	Medium resistance after immersion with asids)kg/cm^2(	Medium resistance after immersion with salts)kg/cm^2(	)kg/cm^2(medium resistance	The mixture
28.98	30.69	290	283	408.3	Ra0
35.11	12.77	305	410	470	Ra30
32.10	19.52	378	448	556.7	Ra50
26.19	9.73	278	340	376.7	Ra100

Table No. (4) also shows the comparison between the decrease in mass when immersed with salts and when immersed with acids, for bitumen samples and with different substitution ratios:

Table (4): results of the mass reduction test for bituminous samples after immersion in salts and acids (10*10*10 cm)

The mixture	Mass loss after immersion in salts %	Mass loss after acid immersion %
Ra0	0.988	1.21
Ra30	0.319	0.28
Ra50	0.369	0.37
Ra100	0.331	3.11

6.1 the effect of substitution ratios on the change of resistance on simple pressure with and without immersion with salts:

We have represented the relationship between the cubic resistance of cast samples (10*10*10cm) on simple pressure and the replacement ratios in the Figure(7).

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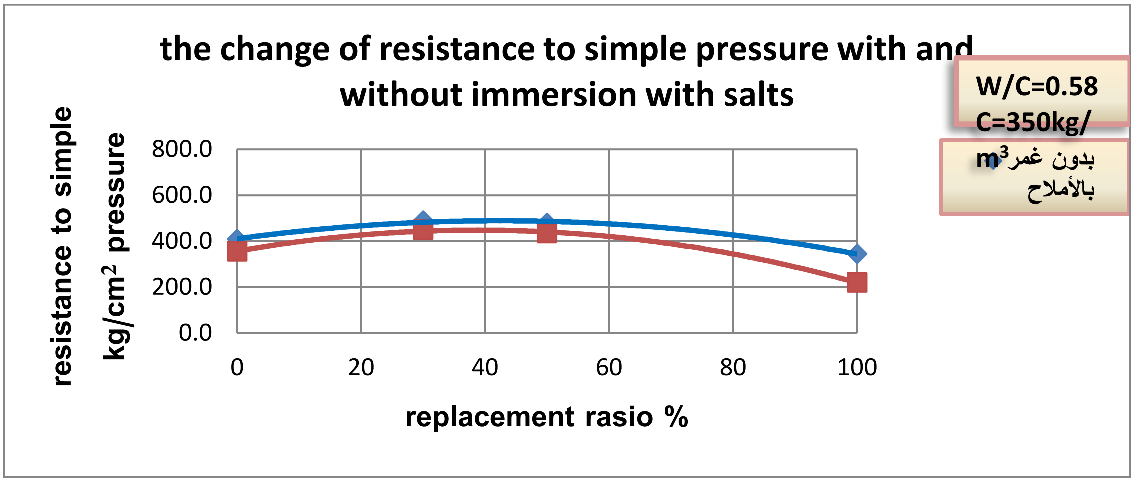

Fig. 7: represents the relationship between the resistance to simple pressure and the replacement ratios

Figure 7 shows that when immersed in salts, the value of the decrease in resistance to simple pressure was slight, at the replacement ratio of 30% it decreased from the value of 500 kg /cm2 to the value of 450 kg/cm2 and at the replacement ratio of 50% it decreased from the value of 480 kg /cm2 to the value of 430 kg/cm2, which indicates that the replacement has contributed to improving the durability indicators of resistance to chloride salts using replacement ratios between 0 and 50%.

6.2.The effect of substitution ratios on the change of resistance on simple pressure with and without acid immersion:

Figure (8) shows the effect of replacing natural pebbles with recycled pebbles on the resistance of samples to simple pressure after immersion in sulfuric acid.

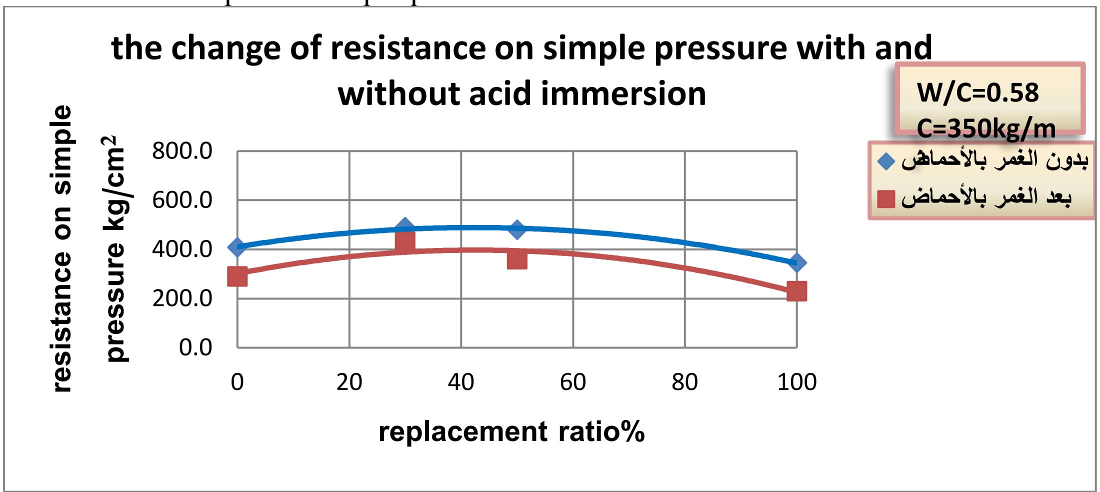

Figure 8: the relationship between the resistance of samples after immersion in sulfuric acid and the replacement ratios

Figure (8) shows that when immersed in acids, the effect of substitution on the resistance to simple pressure was slight: at the replacement ratio of 30%, it decreased from the value of 500 kg /cm2 to the value of 400 kg/cm2, and at the replacement ratio of 50%, it decreased from the value of 480 kg /cm2 to the value of 390 kg/cm2, which indicates that the substitution contributed to improving the durability indicators of resistance to acid attack using replacement ratios between 0 and 50%.

6.3. The effect of substitution ratios on mass loss when attacked by acids and immersion with salts:

Figure (9) shows the effect of replacing natural pebbles with recycled pebbles on mass loss after immersion in sulfuric acid.

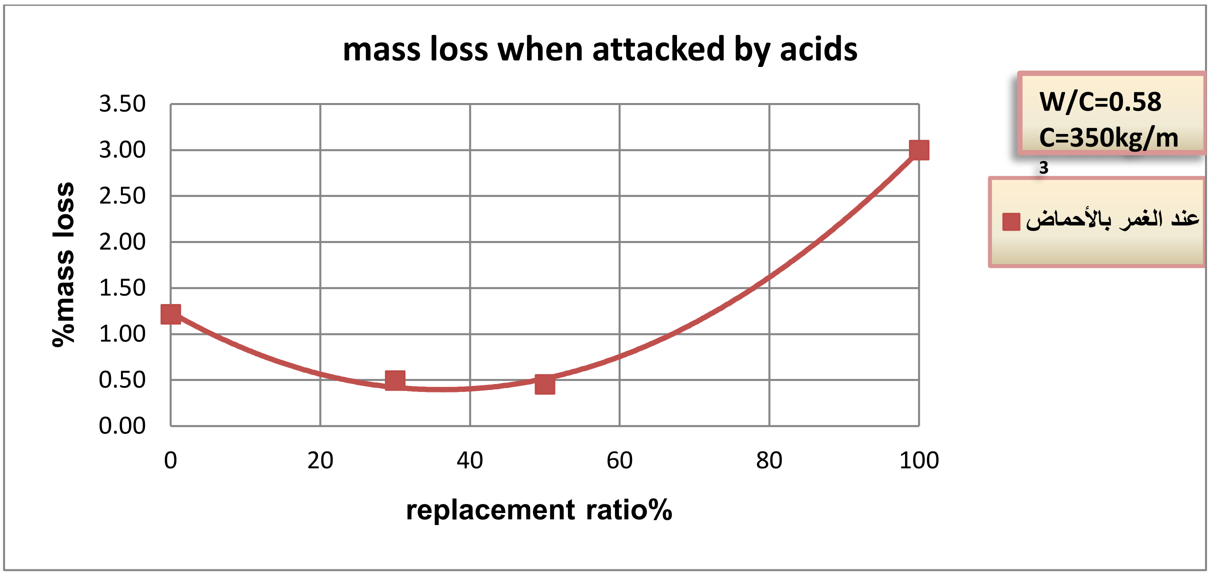

Fig. 9: the relationship between the mass loss of samples when immersed in acids

Figure 10 shows the effect of replacing natural pebbles with recycled pebbles on mass loss after immersion in sodium chloride salt.

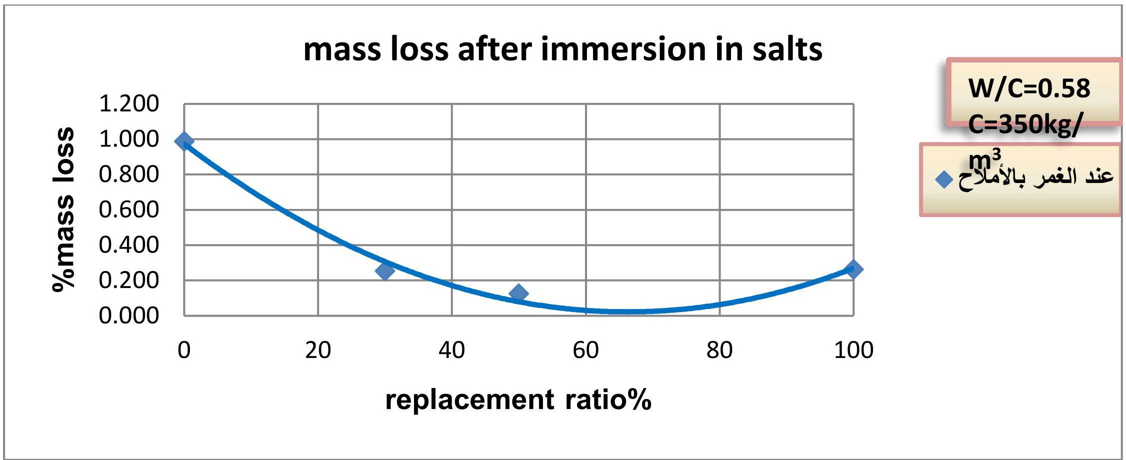

Fig. 10: the relationship between the mass loss of samples when immersed in salts

The blue salt immersion curve shows a decrease in the value of mass loss from the value of 0.98% to the value of 0.31% between the replacement ratios of 0 and 30% and a decrease to the value of 0.36% at the replacement ratio of 50% and the red acid immersion curve shows a decrease in the value of mass loss from the value of 1.21% to the value of 0.28% at the replacement ratio of 30% and a decrease to the value of 0.37% at the replacement ratio of 50%, indicating that the replacement has contributed to the ratios are 0 and 50%, which is a clear indicator of the vulnerability to salts and acids in this area, so that the values of this coefficient increase outside the field and, consequently, the durability of mixtures with high substitution rates decreases.

6.4.The effect of substitution ratios on the loss of resistance when attacked by acids and immersion with salts:

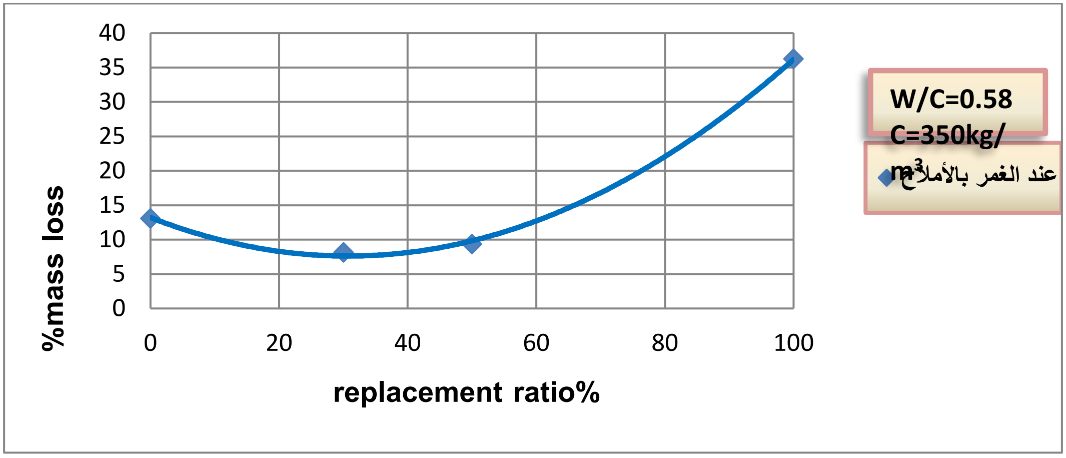

Figure11: the relationship between the loss of resistance of samples in terms of replacement ratios when immersed with salts

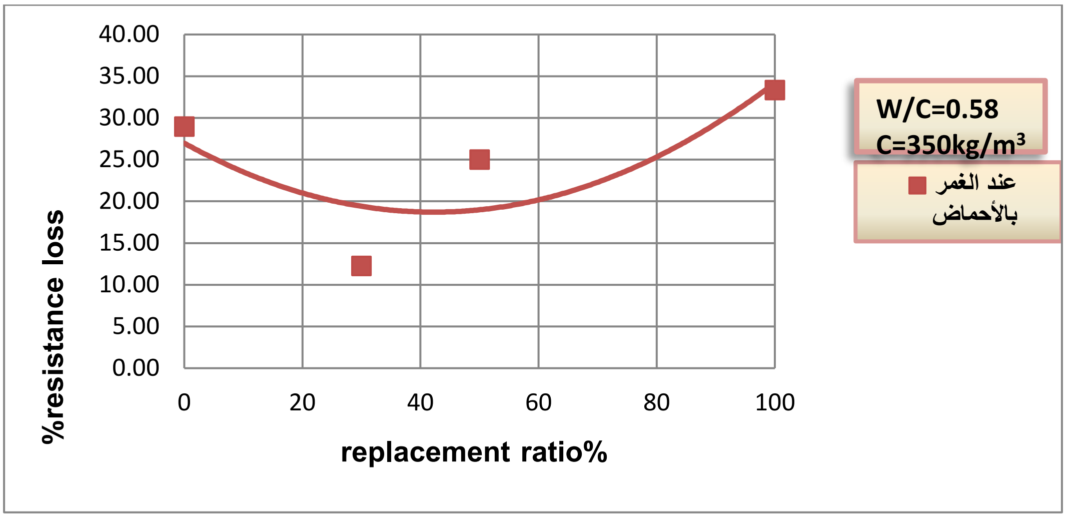

Fig.12: the relationship between the loss of resistance of samples in terms of replacement ratios when attacked by acids.

The Resistance loss curve when immersed in salts shows the vulnerability to immersion at the replacement ratios of 0 and 50%, where the Resistance loss value decreased from the value of 13% to 10%, and the Resistance loss curve when immersed in acids shows a decrease from 28% at the replacement ratio of 0% to 25% at the replacement ratio of 50%, which shows that the replacement has contributed to improving the durability indicators of resistance to chloride salts and acid attack, which is a clear indicator of the positive effect of rubble stones on the durability characteristics related to salts and acids.

The positive performance of recycled stones on the durability of bitumen can be explained by the fact that they contain part of the unreacted Cement, part of which entered the reactions after processing the stones, breaking them and subjecting the fracture surface to a partial grinding process that restored the effectiveness of the partially unreacted cement and its contribution to raising the durability indicators[4].

6.5.The effect of substitution on the change of capillary absorption of bitonic samples:

To illustrate the effect of substitution on the change in capillary absorption, the relationship between the capillary absorption of cylindrical samples D*H =5.4*6 cm) and the substitution ratios was represented according to figure(13):

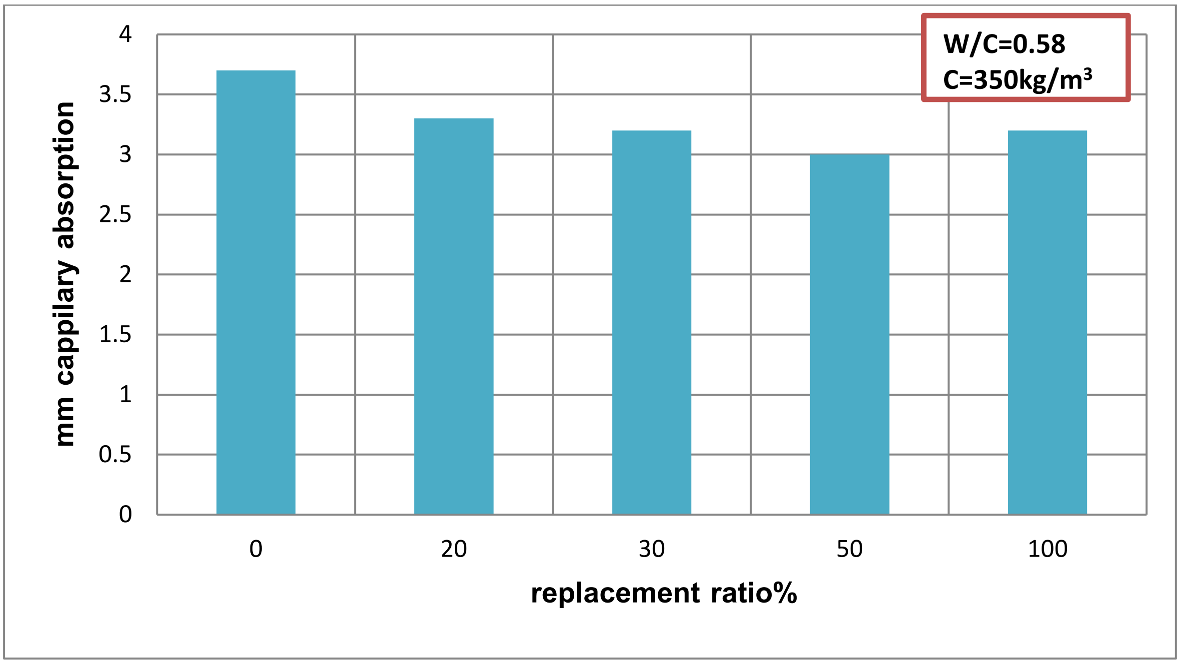

Figure 13: relationship between capillary absorption and substitution ratios

Figure (13) shows the positive effect of increasing the percentage of replacing natural pebbles with recycled pebbles on the capillary absorption values of water, up to the replacement rate of 50%, as the capillary absorption value decreases from 3.7 cm for natural pebbles Peyton samples without replacement to 3.0 cm for Peyton samples by replacing 50% of natural pebbles, equivalent to a decrease of 19% between the ratios of 0 and 50%, to return this value and rise again after the replacement rate of 50% to reach 3.2 cm is at a 100% replacement rate, which corresponds to a completely recycled gravel Piton.

This improvement can be attributed by a decrease in the capillary absorption value when the replacement ratio is increased to the formation of a film of well-resistant and impermeable cement Ruba around the recycled pebbles, which in turn will limit the effectiveness of capillary absorption with water. The use of plasticizer in these mixtures contributes to improving the quality of the binder slurry and, consequently, to improving its patency and ability to lower the capillary absorption value[5].

6.6. The effect of substitution on the change of capillary absorption of bitonic samples:

Here we also represented the relationship between the percentage of maximum water absorption for fully submerged samples for 24 hours and the percentage of replacement of natural pebbles with recycled pebbles. This was done on Cubic samples of bitumen with dimensions (10*10*10cm) completely flooded with water and then dried in a convection oven at a temperature of 105°C for 24 hours.

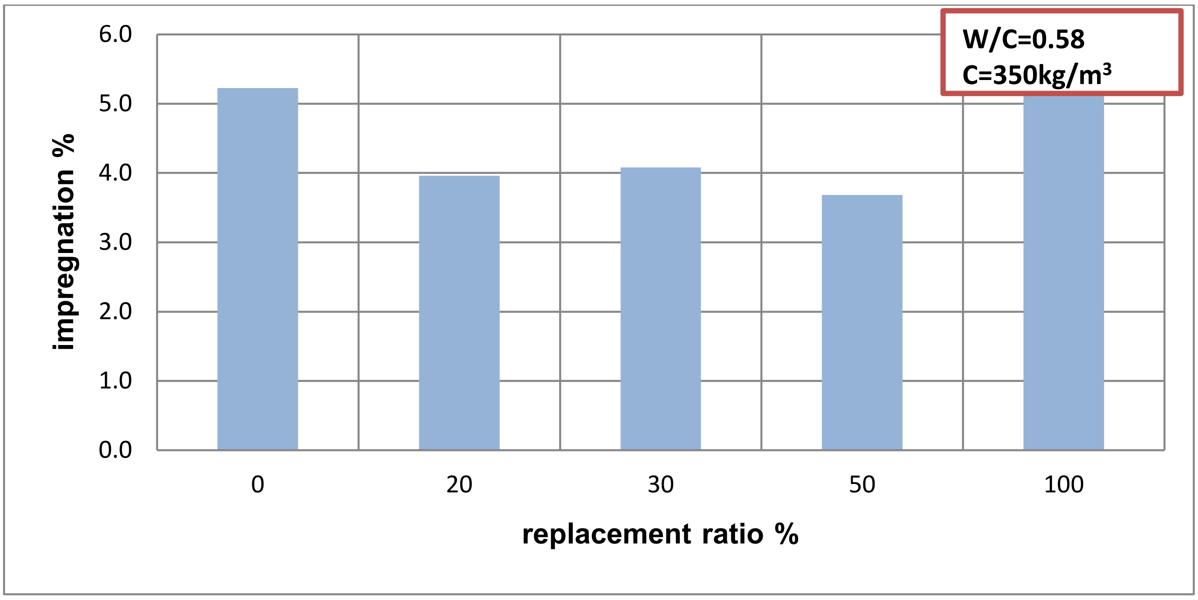

Figure 14: relationship between impregnation change and substitution ratios.

Figure (14) also shows the positive impact of increasing the percentage of replacing natural pebbles with recycled pebbles on the maximum water absorption values, up to the replacement rate of 50%, as the value of maximum water absorption decreases from 5.2% for natural gravel bitumen samples without replacement to 3.7% for bitumen samples with a replacement rate of 50% of natural pebbles, equivalent to a decrease of 29% between 0 and 50% of the 5.5% at a 100% replacement rate, which corresponds to a completely recycled gravel Piton.

This improvement in maximum water absorption when the replacement ratio is increased is also due to the blocking of water penetration ports to the bitumen structure through the formation of a membrane of impermeable cement Ruba around the recycled pebbles, which in turn will limit their water absorption. As in the case of capillary adsorption, the use of plasticizer in these mixtures will contribute to improving the quality of this membrane, thereby improving its patency and ability to reduce the value of maximum water absorption[6]

7. Conclusions and recommendations:

The following points can be recorded as important conclusions of this research:

- Recycled pebbles contribute to improving the durability indicators of resistance to chloride salts up to a replacement rate of 50%.
- Recycled gravel plays the same role in reducing the effect of the acidic medium, between the replacement rates of 0 and 50%
- Even at high replacement ratios, the value of resistance losses and mass losses when immersed in acids and salts remains limited .
- One of the most important recommendations is the possibility of using bitumen produced from recycled pebbles in facilities that are exposed to harsh conditions, such as proximity to marine environments and generally vandalized.
- Recycled pebbles, when used in bitumen with a high-performance plasticizer, maintain mechanical properties and durability properties related to water permeability, such as capillary absorption and maximum water
- The use of plasticizer clearly contributes to improving the performance of recycled pebbles in bitumen by activating their coating with a well-resistant cement film that reduces permeability and impregnation.

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- Recycled pebbles retain their positive effect on the studied durability indicators even when used with a replacement ratio of up to 100%.
- The use of plasticizers in the bitumen, which includes recycled Pebbles, is considered the most feasible and effective factor in improving the performance of these pebbles in the bitumen and significantly reducing their negative impact on the resistance and durability properties of the bitumen.

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