International Journal of Advanced Engineering and Nano Technology (IJAENT)
ISSN: 2347-6389, Volume-2 Issue-11, October 2015

Studying the Effect of Using Nano-Materials on the Performance of Cold Recycled Asphalt Pavement Mixes

Abdelzaher E. A. Mostafa

Abstract*— Recycling asphalt pavement creates a cycle of reusing materials that optimizes the use of natural resources. Reclaimed asphalt pavement (RAP) is a useful alternative to virgin materials because it reduces the need to use virgin aggregate.[1] In this investigation, it has been studied the effect of nano material such as nano silica and nano carbon on the mechanical properties of marshall specimen. Tests were carried out on cold RAP with slow setting emulsion. Optimum percent of emulsion was obtained from previous research. After determination the optimum percent of nano silica and nano carbon tubes , these percent used with optimum percent of latex to studding the improvement in mechanical properties. The results showed that, there is improvement in stability about 150% by used nano materials.

***Index Terms*— Cold Asphalt Mixtures; Asphalt Emulsions; Polymers; Nano-Materials**

I. INTRODUCTION

Existing asphalt pavement materials are commonly removed during resurfacing, rehabilitation, or reconstruction operations. Once removed and processed, the pavement material becomes RAP, which contains valuable asphalt binder and aggregate.[1]

The main purpose of recycling is to reuse existing pavement material for rehabilitation of pavements. The most important advantages of recycling are conservation of resources and money. Cold-mix recycling is one of the various recycling methods available today. Cold-mix recycling can result in a stable pavement at a total expenditure of 40 to 50 percent less than that required by conventional construction methods.[2] However, like conventional hot mix asphalt, cold-mix asphalt used for recycling must be designed properly to ensure reliable performance. The unique features of cold recycled mixes are time temperature effects (curing) due to the presence of the water and/or volatiles and the slower binder softening rate.[3] Hence, proper considerations should be given to changes in mixture properties with time and target reduction of aged binder consistency in the mix design.[4]

Old asphalt materials can be recycled using cold, warm or hot production methods, and the addition of new binder, asphalt mixture, water or mineral aggregate in the old asphalt can be performed either in the plant or on site. Recycled asphalt can be used for wearing courses, basecourses or roadbases. Cold and warm methods are mainly intended for roads with low or medium traffic volumes, while hot recycling is also suitable for roads with high traffic volumes. In cold and warm recycling, the proportion of recycled asphalt may be up to 100%, while in heated plant recycling the proportion may be 10-40%. In cold plant recycling, the new binder consists of bitumen emulsion.[5]

The increasingly used of bitumen emulsion in road construction is no longer a new issue ever since the introduction of bitumen emulsion dated back to the early of 20th century. It was first introduced in the 1900's with initial application focused on dust control and later gains interest in farm and market roads paving which experiences relatively low traffic stress.[6, 7]

Bitumen emulsion can be produced by mixing hot asphalt binder with water containing emulsifying agent using a colloid mill or other dispersion devices.[8] Manufacturing methods may affect the properties of the final emulsion. Sometimes, polymers are added during the manufacturing process to produce polymer modified bitumen emulsion which possesses better properties compared to the conventional bitumen emulsion. There are several ways to add polymer as for example, pre-blending in the soap solution, co-mill or post addition as indicated in Figure 1.[9]

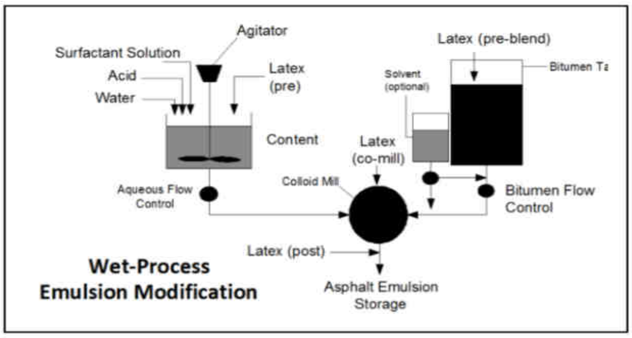


Figure 1: Bitumen emulsion modification process in manufacturing industry.[9]

One way to improve the use of cold technologies under high traffic loads is through the use of high performance binders such as Polymer-Modified Bitumen Emulsions (PMBE).In all cases, PMBE shows improved rheological properties of the residue after breaking when compared to unmodified bitumen emulsions. Still, PMBE are characterized in the same way as unmodified emulsions, binder content, viscosity and particle size (especially the absence of coarse particles, i.e. residue on sieves) being key properties. The main difference lies in the rheological properties of the residue.[9]

Revised Version Manuscript Received on October 02, 2015.

Abdelzaher E. A. Mostafa, Associate Professor, Department of Civil Engineering, Mataria School of Engineering, Helwan University, Ca iro, Egypt.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

In recent years, some researchers have started to work on the improvement of asphalt materials with nanomaterials in asphalt cement and emulsions. There are various nanomaterials which have been or have potential to be used in asphalt modification; such as nanoclay, nanosilica, nano-hydrated lime, nano-sized plastic powders, or polymerized powders, fibers, and nanotubes.[10]

This research studies the effect of nano-material such as nanocarbon tube and nano-silica on the mwchanical properties of emulsion in cold reclaimed asphalt pavement CRAP.

II. LITERATURE REVIEW

In 2007, Federal Highway Administration (FHWA) created an Expert task group (ETG), known as the RAP ETG, for the use of RAP in the construction and rehabilitation of flexible pavements. It is comprised of RAP experts from FHWA, State transportation departments, the American Association of State Highway and Transportation Officials (AASHTO), the National Asphalt Pavement Association (NAPA), the National Center for Asphalt Technology (NCAT), and people from the industry and academia. The purpose of the ETG is to advance the use of RAP in asphalt paving applications by providing State transportation departments and the industry with information emphasizing the production of high-quality high RAP mixtures, the performance of asphalt mixtures containing RAP, technical guidance on high RAP projects, and RAP research activities.[1] Giuliani Fandet. Al.[11]compared the performances of asphalt concrete prepared with RAP and cold-stabilised with bituminous emulsion and cement, and those of asphalt concrete prepared with the same binders and by the same technique, but using virgin mineral aggregates. Research studied the influence of several variables that were taken into consideration on both the mixtures produced by virgin mineral aggregate and the ones containing RAP. Table 1 briefly shows the influence of single project parameters on the final mechanical performances of asphalt concrete. This table anyway, although it provides an easily understandable qualitative evaluation, cannot be considered complete for comprehension of all the factors that may influence the good result of the roads cold recycling process. Cold recycling of asphalt pavements involves different factors, some of which are quite difficult to control, especially on site, such as weather conditions, the heterogeneity of the lots and the working plan of contractor.[11] Nevertheless, the analytical approach to this recycling technique has made it possible to evaluate the influence of the different independent variables and has allowed to quantify the structural contribution of the various binders used. In the cold stabilization process the cement plays an important role, since it contributes significantly to the increase of mechanical strength, but it is also an effective regulator in breaking phenomena of the bituminous emulsion. The laboratory tests showed that mixtures with cement as additive provide the best performances if compacted with a high energy and a low percentage of emulsion. An excessive quantity of liquids reduces the efficiency of the compaction process, preventing from the reaching of an optimal density and increasing the water-cement ratio.[11]

Table 1: Influence of the different variables in the experimental study[11]

	Mixtures with virgin aggregates			
	Compr. strength 7 days	Compr. Strength 28 days	Indirect tensile strength	Dynamic modulus
% emulsion	-	-	+	+
% cement	+	++	=	++
Compaction	=	=		=
curing time	+	+	++	=
	Mixtures with RAP			
	Compr. strength 7 days	Compr. strength 28 days	Indirect tensile strength	Dynamic modulus
% emulsion	-	-	=	+
% cement	+	++	+	++
Compaction	+	++		=
curing time	+	+	+	+

Given the composite nature of asphalt mixture, the potential for improvements in the engineering properties of asphalt mixture through the application of nano-technology is significant. The mechanical behavior of bituminous materials depends to a great extent on structural elements and phenomena which are effective on a micro- and macro-scale. The nano-modification of materials is start with engineering modifications to the molecular structure with an aim to affect the bulk properties of the materials. The nano-modification of bituminous materials has the potential to open up whole new uses and classes of bituminous materials. Most of the current bitumen modifiers in the market do not work on a nano-scale. They don't do anything to the chemistry of the bitumen, rather just improving specific properties such as binding and flexibility. Nano-scale modifiers can react with bitumen and change the chemistry and the molecular structure of the bitumen. This catalytically reaction may cause better properties.[12]

Timothy R and et. Al.[13] made an effort to better characterize asphalt emulsions that are typically used in cold in-place recycling (CIR) applications. A simple approach was presented that treated the cured residue as asphalt binder and applied the standard Superpave specifications to the material. A literature review examined methods that have historically been used to produce, characterize, and apply asphalt emulsions.

Four emulsions were tested in this project: CRS-2P, CSS-1, EE, and HFMS-2P. The emulsions were cured two ways, the first being allowed to sit overnight in a pan at room temperature, and the second being a modified RTFOT approach. Air cured samples were also aged in the PAV. These residues were then tested with the BBR and DT at low

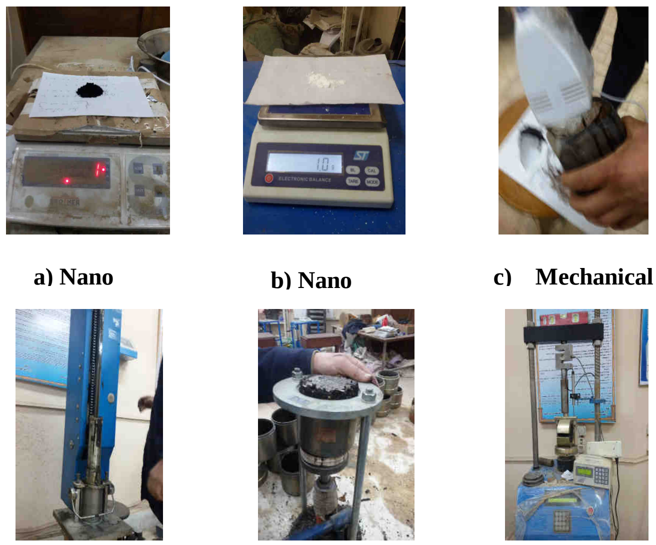
Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

temperatures and with the DSR at high and intermediate temperatures. AASHTO MP1 specifications were applied in order to characterize the emulsions by PG grade. Following this, AASHTO MP1a specifications were followed in order to find the critical cracking temperature of the emulsions. Master curves were constructed from the DSR tests of complex shear modulus vs. frequency. Finally, a sample mix design was presented using these emulsions and an empirical equation to predict the dynamic modulus of the mixture.[13]

III. EXPERIMENTAL WORK

This research studies the improvement in mechanical properties in cold RAP by adding nano materials to the used emulsion as a percent of its weight. To achieve the optimum percent of nano-silica and nano-carbon, five percent of nano silica (1, 3, 5, 7, and 9%) and four percent of nano carbon tube (0.01, 0.1, 0.5, and 1%) were mixed with emulsion.Nano silica and nano carbon tube mixed with emulsion by mechanical mixer.

ASTM D5581 - 07a(2013) Marshall tests were carried out on specimen prepared by 3.5% of emulsion and 3% water of dry aggregate weight (as optimum percent from the previous research). Figure2 show the experimental work steps in the laboratory.



a) Nano b) Nano c) Mechanical

d) Marshall e) Ejection Marshall f) Marshall

Figure 2: Experimental Work Steps

After determination the optimum percent of nano-silica and nano-carbon, research studied the effect of this optimum percent on polymer modified emulsion. Marshall Specimen were prepared with polymer modified emulsion with 3.5% emulsion and 3% water as previous additionally 3% of latex polymer as a percent of emulsion. All results compared with Marshall Specimen with bure emulsion to recognize the improvement.

IV. RESULTS

Effect of nano-silica on emulsion used in cold RAP is illustrating in Table 2. Increasing percent of nano-silica increase the stability and rigidity until the percent reach to 7% then 9% percent have a negative effect as shown in Figure 3, and 4,While flow of the specimen decreases with the increase in nano-silica as shown in Figure 5.

Table 2: Effect of Nano-Silica on Mechanical Properties

	Cont	Nano-Silica				
		1%	3%	5%	7%	9%
Stability (Kg)	645	657.5	930	1305	1317	950
Flow (mm)	20	19.75	15	13.5	12	10.5
Rigidity (Kg/mm)	32.25	33.29	60	96.67	107	90.48
Increasing in Stability %	----	2	44	102	104	47
Decreasing in Flow %	----	-1	-23	-33	-39	-48
Increasing in Rigidity %	---	3	86	200	233	181

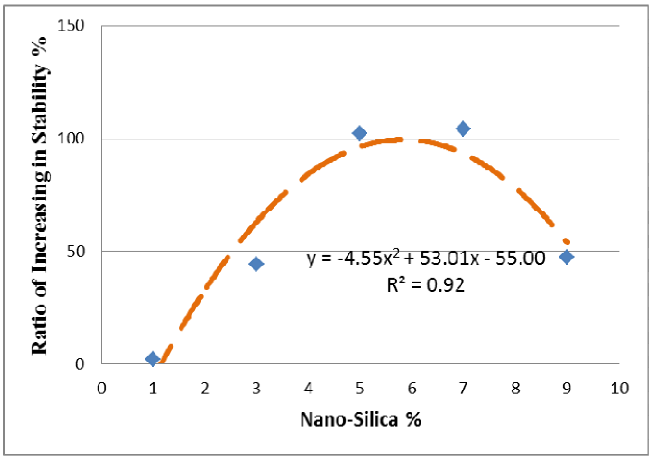


Figure 3: Effect of Nano-Silica on Ratio of Increasing in Stability

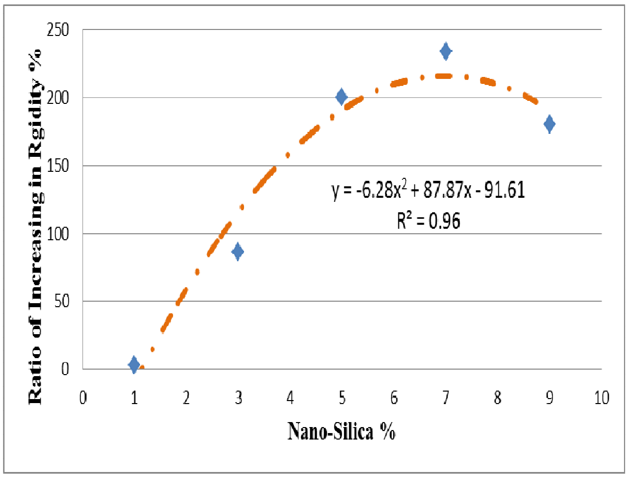


Figure 4: Effect of Nano-Silica on Ratio of Increasing in Rigidity

*Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.*

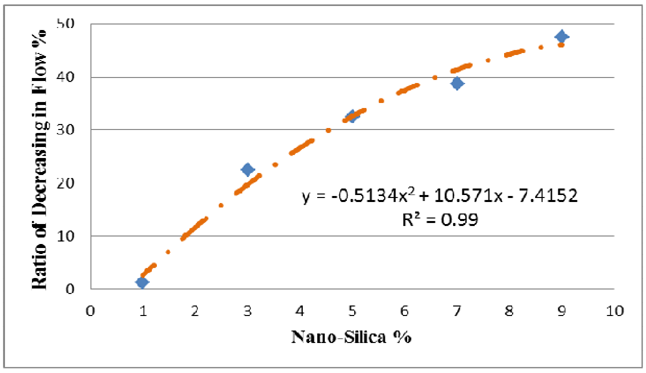


Figure 5: Effect of Nano-Silica on Ratio of Decreasing in Flow

From the results, the optimum percent of nano-silica is 7%. This percent increase the stability 104% than the control, and increase the rigidity 233%, while flow is decreasing 39%. To obtain the optimum percent of the trends for stability and rigidity and still acceptable, the equations of the trend should differential and equality by zero as illustrated in Table 3.

Table 3: Optimum Percent of the Trend For Nano-Silica

	Equation	1st Differential	Optimum
Stability	$y = -4.55x^2 + 53.01x - 55.00$	$y` = -9.1\,x + 53.01 = 0$	x = 5.83%
Rigidity	$y = -6.28x^2 + 87.87x - 91.61$	$y` = -12.56\,x + 87.87 = 0$	x = 7%

Table 4 illustrates the effect of nano-carbon tube on emulsion used in cold RAP. Stability and rigidity areincreasing with the increase in percent of nano-carbon until percent of 0.5% then negative effect were occurred as shown in Figure 6, and 7. While specimens flow is decreases with the increase in nano-silica percent as shown in Figure 8.

Table 4: Effect of Nano-Carbon on Mechanical Properties

	Control	Nano-Carbon			
		0.01%	0.1%	0.5%	1%
Stability (Kg)	645	675	1050	1625	790
Flow (mm)	20	20.25	17	15.25	14.5
Rigidity (Kg/mm)	32.25	33.33	61.76	106.55	54.48
Increasing in Stability %	----	5	63	152	-9
Decreasing in Flow %	----	1.25	-15	-24	-28
Increasing in Rigidity %	---	3	92	231	25

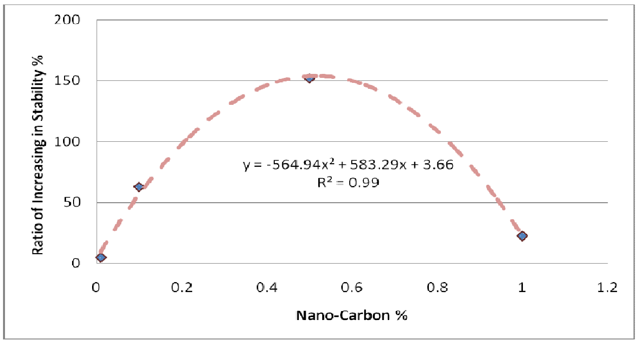


Figure 6: Effect of Nano-Carbon on Ratio of Increasing in Stability

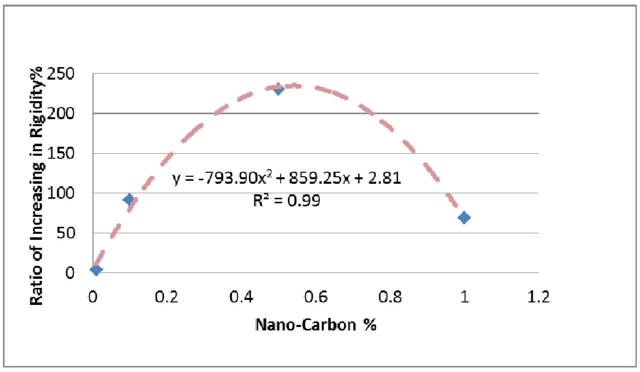


Figure 7: Effect of Nano-Carbon on Ratio of Increasing in Rigidity

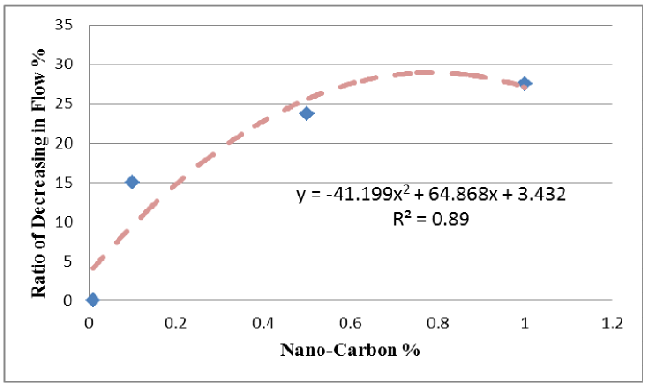


Figure 8: Effect of Nano-Carbon on Ratio of Decreasing in Flow

From the results, the optimum percent of nano-carbon is 0.5%. This percent increase the stability 150% than the control and increase the rigidity 231%, while flow is decreasing 24%. To obtain the optimum percent of the trends for stability and rigidity, the equations of the trend should differential and equality by zero as illustrated in Table 5.

Table 5: Optimum Percent of the Trend For Nano-Silica

	Equation	1st Differential	Optim.
Stability	$y = -564.94x^2 + 583.29x + 3.66$	$y` = -1129.9\,x + 583.29 = 0$	x = 0.5%
Rigidity	$y = -793.90x^2 + 859.25x + 2.81$	$y` = -1587.8\,x + 859.25 = 0$	x = 0.54%

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

Table 4 compares the results of stability, rigidity, and flow between samples prepared by nano-modfied emulsion and samples prepared by nano-polymer modified emulsion.

Table 4: Comparison between nano-modfied emulsion and nano-polymer modified emulsion.

	Cont.	Nano silica		Nano carbon	
		Nano	Nano+ Latex	Nano	Nano+ Latex
Stability (Kg)	645	1317.5	1625	1625	1800
Flow (mm)	20	12.25	11.25	15.25	14.5
Rigidity (Kg/mm)	32.25	107.55	144.4	106.55	124.14

Figures 9,10, and11 shows the effect of optimum percent of nano silica and nano carbon tube on the stability, rigidity and the flow of marshall test made by polymer modified emulsion respectively.

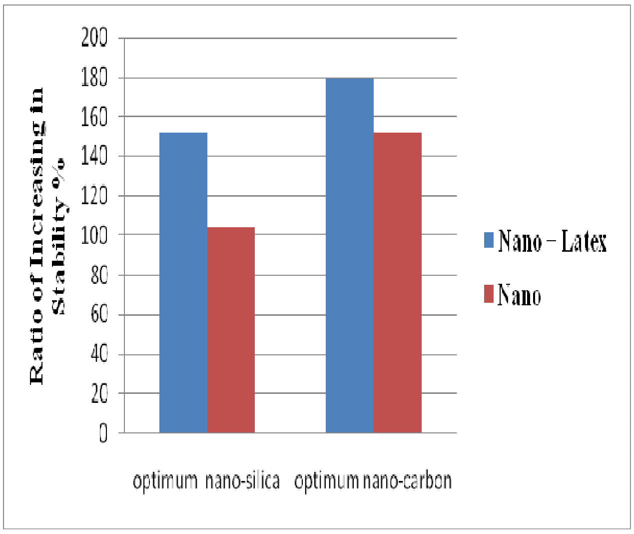


Figure 9: Effect of optimum nano and optimum polymer on Stability

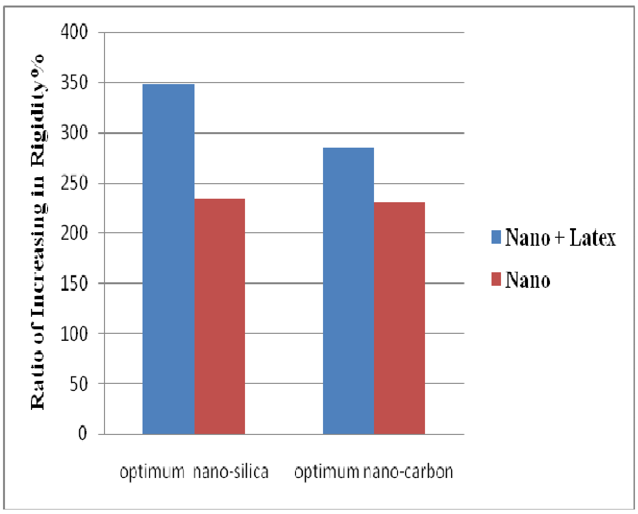


Figure 10: Effect of optimum nano and optimum polymer on Rigidity

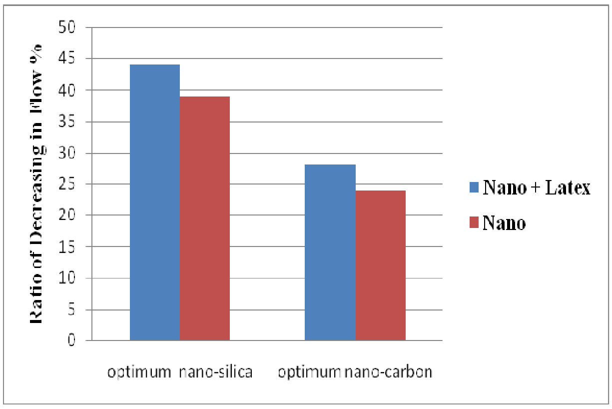


Figure 11: Effect of optimum nano and optimum polymer on Flow

From the results, using polymer improve the mechanical properties. Latex increase the stability 152% in case of nano silica and 179% in case of nano carbon. Also, latex increases the rigidity 348% in case of nano silica and 285% in case of nano carbon While the flow decrease 44% in case of nano silica and 28% in case of nano carbon.

V. CONCLUSION

Effect of nano material such as nano-silica and nano-carbon on the mechanical properties of marshall specimen were studied to achieve the optimum percent. After determination the optimum percent of nano-silica and nano-carbon, this percent used with optimum percent of latex to studding the improvement in mechanical properties.

1) Nano silica and nano- carbon improve the mechanical properties.
2) Optimum percent of emulsion are 7% nano silica and 0.5% nano carbon.
3) Optimum percent of nano-silica increase the stability 104%.
4) Optimum percent of nano-carbon increase the stability 150%.
5) Add Latex to optimum nano silica increase the stability 152%, while add Latex to optimum nano carbon increase the stability 179%.

Therefore it is recommended to study the economy of using nano-materials as additives to be used to enhance the performance of cold in-place recycling mixes.

REFERENCES

1. J.-Y. Yu, P.-L. Cong, and S.-P. Wu, “Laboratory Investigation on the Properties of Asphalt Modified with Epoxy Resin,” Journal of Applied Polymer Science, vol. 113, pp. 3557–3563, 2009.
2. Audrey Copeland. (2011). “Reclaimed Asphalt Pavement in Asphalt Mixtures: State of the Practice”,Federal Highway Administration 6300 Georgetown Pike McLean, VA 22101
3. Guidelines for Cold In-Place Recycling, (1991).“Asphalt Recycling and Reclaiming Association”, Annapolis, MD.
4. Pavement Recycling Guidelines for Local Governments - Reference Manual. (1987). Report No. FHWA-TS-87-230, FHA, U.S. Department of Transportation, Washington DC.
5. L.E. Santaucci and M.T. Hayashida. (1983).“Design and Testing of Cold-Recycled Asphalt Mixes”, Proceedings of AAPT, Vol. 52.
6. Torbjörn Jacobson. (2002) “Cold Recycling Of Asphalt Pavement - Mix In Plant”, Swedish National Road and Transport Research Institute SE-581 95 Linköping Sweden
7. F. L. Roberts, P. S. Kandhal, E. R. Brown, D. Y. Lee and T. W. Kennedy. (1996). “Hot Mix Asphalt Materials, Mixture Design and

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

Construction". United States of America: National Centre for Asphalt Technology.
8. N. Thom. (2008). "Principles of Pavement Engineering". London: Thomas Telford.
9. M. A. Shafii, M. Y. A. Rahman, and J. Ahmad. (2011). "Polymer Modified Asphalt Emulsion". International Journal of Civil & Environmental Engineering. 11(6): 43–49.
10. Didier Lesueu. (2011). "Polymer Modified Bitumen Emulsions", Materials R&D Manager, Rue de l´Industrie, 31, 1400 Nivelles – Belgium
11. Zhanping You "Nanomaterials in Asphalt Pavements. (2013). "Technological University, Department of Civil and Environmental Engineering, Michigan Houghton, Michigan, 49931-1295, USA, DOI:10.6135/Ijprt.Org.Tw/2013.6(3).Iv, ISSN 1997-1400 Int. J. Pavement Res. Technol. 6(3)
12. Felice Giuliani, Silvia Rastelli. (2004). "An Analytical Approach To Evaluate The Performance Of Cold Recycled Asphalt Mixtures", Dipartimento Di IngegneriaCivile, Dell'ambiente, Del Territorio E Architettura Università Degli Studi Di Parma, Italia.
13. Resperio. (2008). "IntegraBase & Nanotechnology: Modifying Asphalt on a Molecular Level". www.resperion.com.

Dr. Abdelzaher Mostafa is an Assoc. Prof. of Civil Engineering, Helwan Un, Cairo, Egypt. He was born in Feb 29th, 1968 and he graduated in 1991 from Department of Civil Engineering, with grade excellent with honor. He worked as a demonstrator from 1991-1996 when he was awarded the Master Degree in Civil Engineering in the field of Traffic engineering. In 2000 he started his PhD Study at Carleton University, Ottawa, Canada and in 2005 he was awarded the PhD degree in Civil Engineering in the field of Airports. He worked as a lecturer in the Department of Civil Engineering for 5 years until he was promoted to Assoc. Prof. of Civil Engineering in 2011. During his work, Prof. Mostafa was the Head of Civil Engineering Material laboratory, and quality assurance unit. Prof. Mostafa have participated in 10 research projects, supervising more than 20 masters and PhD thesis and published more than 30 papers in journals and international conferences. Finally Prof. Mostafa is a member of Egyptian Engineering Syndicate since 1991, reviewer of many journals and conferences as well as a highway and airport consultant.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.