Predicting Some Properties of Polythene Modified Asphalt Concrete Mixtures from Single Face Compaction Using Newton's Third Law Application

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Abstract:

Laboratory techniques whether the Marshal or Hveem design procedure used for characterizing asphalt concrete mixes in order to simulate flexible pavement behaviour and performance usually requires compaction of the asphalt concrete samples on both faces irrespective of traffic category. However, in actual construction of flexible pavements in the field, compaction of the pavement is done only on the face of the pavement above the base/sub-base layer which is in slight contrast with the laboratory procedure. Pavement engineers have long answered the question of this contradiction by the theory of Newton's Third Law of Motion – "to every action there is an equal and opposite reaction". In order words as compaction in the field is carried out on the top layer above the base layer the reverse side of the pavement offers an equal and opposite reaction force. Therefore, the major aim of the study is to solve the problem of excessive compaction leading to time and energy waste and reduction of wear and tear on the compacting machine which is usually very expensive to buy. On this basis the present study sought to replicate true field conditions in the laboratory by compaction of the asphalt concrete samples on a single face and comparing the results with that of double face compaction which resembles actual field conditions. The laboratory investigation involved characterizing polythene modified asphalt concrete samples submerged in moisture conditions between 1-5 days with respect to Retained Marshal Strength (RMS), Retained Strength Index (RSI) and Swell Index (SI) of the samples for both single and double face compactions. Furthermore, model equations were obtained having a correlation (R) such that the results from double face compaction can be determined from that of single face compaction for each material property considered as follows: R = 0.888 for RMS and 0.916 for RSI and 0.918 for SI in conclusion the high values of R actually suggest that single face compaction can actually represent true field conditions and also closely simulate results of compaction on both face with a high degree of accuracy.

Keywords: single and double face compaction, retaned marshal stability, retained strength index, and swell index.

1.0 Introduction

The purpose of this research is to comparatively hot mix asphalt concrete properties by using Bruce Marshal design principle side by side with the Newton's third law. Previous studies using either Hveem or Marshal Design procedures (MDP) in asphalt concrete adopts compaction of asphalt briquettes on both faces irrespective of traffic category. However, the present study seeks the introduction of single face compaction that can accurately simulate double face compaction while reducing time waste, wear and tear and energy loss.

Durability can be defined as the degree of resistance of a bituminous binder to these changes. Furthermore, a recent study by Igwe *et al*., (2017), defined durability as the resistance offered by bituminous pavement against gradual disintegration of the wearing course due to the actions of temperature, traffic, moisture and construction practices

Asphalt Concrete Pavement is also known as a Bituminous Pavement or Flexible Pavement. A large portion of these roads here in Nigeria is the Flexible Pavement. Flexible pavement involves different strata of different materials, various combinations of irregular traffic loading and varying environmental conditions such as temperature, moisture and oxidation rates Igwe *et al*., (2009). A realistic prediction of the long-term service life of asphalt pavement is one of the most challenging tasks for pavement engineers in Highway Engineering. The Asphaltic or Flexible Pavement gains its strength from the different arrangements of several layers of materials Magdi, (2014).

These properties of asphalt mixtures are very complicated and sometimes very difficult to predict Xiao *et al*. (2007). But the properties of its constituents are relatively less complicated and easier to characterize. Garica et al. (2008) argued that the most important Hot Mix Asphalt (HMA) property influencing the structural response of a flexible pavement is the Hot Mix Asphalt (HMA) stiffness modulus (E_{HMA}). Thus, flexible pavement design methods based on elastic theories require that the elastic properties of the pavement materials be known Brown et al. (1989).

Candle wax as a road material is added to bitumen and aggregates to achieve certain preferred properties like reduced asphalt mixing temperature and higher stiffness of the pavement. Also, present day studies have showed how candle wax can enhance durability of asphalt pavement wearing course when there are poor or no drainage facilities. To this effect, Igwe *et al*. (2017), did a comparative study on the effect of candle wax as a non-bituminous modifier on void and flow properties of the asphalt concrete. It was evident in their study that air voids reduced significantly for all traffic categories

Also, a study by Igwe et al (2017), where they considered improving durability of asphalt pavement wearing course when fully submerged in water using candle wax as a water proofing agent. They observed that with the inclusion of candle wax to asphalt pavement wearing course there was an improvement in the durability of the pavement. It also improved the stability/strength of the pavement, and the pavement life. Furthermore, they concluded that candle wax can be used as a water proofing agent to enhance durability of the wearing course in design and construction of asphalt pavements when no measures are taken to provide a good drainage system.

. A study by Igwe et al. (2017) re-evaluated the fact that flexible pavements fail faster in undrained conditions. To this effect, they considered the use of hydro carbon fillers obtained from recycled polyethylene wastes (RPEW) such as pure water sachet to increase durability of the bituminous pavement when submerged in water, because for a fact, hydro-carbon is present in both the bitumen which is used as a binder and in the polyethylene. Igwe *et al*., (2017);

Research by Igwe (2015), using varying amounts of rubber latex ranging from 0-3% at the asphalt content of the asphalt concrete mixture, and the dynamic moduli of the rubberized concretes determined using varying frequencies of 0.1, 1,5,10, and 25Hz respectively, showed that the material property of asphalt concrete and in particular, dynamic modulus E*, is influenced greatly by the changing air voids content for a rubber latex modified pavement. He also came to the conclusion that the rate of change of log E* with air voids is inversely linear; that is, log E* increases with decreasing air void content.

The high stiffening effect observed with the addition of quicklime at high temperature disappears below room temperature. The stiffening effect of quicklime is temperature-dependent Al-Tameemi et al., (2015). It important to note that hydrated lime is known to reduce chemical ageing of bitumen stiffens the pavement more than normal mineral filler above room temperature; it also acts as an anti-stripping agent

Authors such as Al-Saffar (2013), Huang, Bird, & Heidrich (2007) have also reported on the incorporation of several filler types into asphalt in its mix design; including waste glass, lime stone powder, and glass powder. Cabeza *et al*. (2010) indicates that there are several other filler materials usable in construction (e.g. ceramic, bricks, quarry dust, fly-ash, lime etc.). Such materials may be used primarily to pave floors in garages parking lots, sidewalks, playgrounds and parks. These materials are generally classified based on their origin, which can be from plants, synthetics or **Improving Densibility and Mix Design Properties of Modified Asphalt Concrete for Esal>10^6 using Mineral Fillers**

2.0: MATERIALS AND METHOD

2.0.1 Material Sampling

The materials used for this study were asphalt cement, fine and coarse aggregates, and pure water satchet bags (Polyethene). The asphalt cement used was obtained from a private Construction Company, Setraco situated in Port Harcourt Local Government Area of Rivers State, Nigeria. On the other hand, the coarse and fine aggregate used were obtained directly from market dealers at Mile 3, Diobu, Port Harcourt. The Polyethene used as modifier was obtained as wastes from the waste baskets around Choba community.

2.0.2 Laboratory Tests

The laboratory tests that follow thereafter are

I. specific gravity,
II. grading of asphalt
III. and sieve analysis of the aggregates

the sieving grades were now used to plot straight line graph and determines the mix blend

2.0.3 Sample Preparation

Preparation of the sample was preceded by aggregate gradation and blending. The straight line method of blending which allows for only two aggregates to be blended was adopted. After aggregate gradation and blending.

The procedures adopted in this journal is the Hveen and Marshal Design Principle (MDP) which involved compaction of asphalt concrete in the briquette on both faces at 75 blow being for heavy traffic category and Newton's Third Law Principle (NTLP) which emulates (MDP) but on one face respectively.

2.0.4 Models Applied

The models are the mathematical equations to evaluate the loss of strength in the asphalt concrete.

Retained Strength Index (RSI) this is a model that expresses strength reduction in asphalt concrete wearing course. It expressed in percentage. (RSI) it is used to measure the effect of water damage on the Marshall stability for the asphalt concrete mixtures exposed to moisture conditions, according to Ali (2013) mathematically. The lower the index value, the lower the less durable pavement becomes.

$$RSI = \frac{S_i}{S_0} \times 100 \quad (1)$$

Where;

RSI= retained strength index

S_i= stability after immersion at time t_i or maximum stability of conditioned specimen

S_0= stability before immersion or maximum stability of unconditioned specimen.

Durability index which is used in predicting and controlling moisture damage in asphalt mixtures that is the ability for an asphalt mixture to resist breaking down when submerged in water is being considered in two parts;

Swell Index (SI) The percentage increase in volume of a specimen due to moisture absorption is refer to as the swelling index of that sample. It is calculated as

$$SI = \frac{v_1 - v_0}{v_1} \times 100 \quad (2)$$

Where:

SI = Swell Index
v_i = volume of sample after immersion at t_1
V_o = volume of sample before immersion at t_0

3.0: RESULT

Table 1. Materials Classification Test Results

Materials	Asphalt	Course aggregate.	Fine aggregate.	Polyethene
Specific gravity	1.01	2.59	2.53	
Grade of asphalt	60/70	-	-	-
Mix proportion (%)	-	62	38	-
Viscosity (mm/s)	68.1	-	-	-
Softening point (o^c)	49.5	-	-	-
Penetration value (mm)	67.5	-	-	-
Melting point (o^c)				110

ISSN 2229-5518

Table 2: Schedule of Mix proportion for Aggregates (Gravel & sand)

Sieve (in.)	Sieve (mm)	Specification Limit	% passing Aggregate A (Gravel)	% passing Aggregate B (Sand)	Mix Proportion (0.62A+0.38B)	Tolerance
3/4”	19.1	100	100.0	100.0	100.0	±6
½”	12.7	76-98	90.4	100.0	94.0	±6
3/8”	9.52	64-79	41.6	100.0	63.8	±5
No. 4	4.75	40-60	17.1	98.9	48.2	±5
No.10	1.18	23-38	8.6	83.0	36.9	±4
No. 40	0.425	7-20	6.3	13.0	8.8	±4
No. 80	0.300	5-13	4.8	3.0	4.1	±3
No. 200	0.075	3-8	3.8	0.2	2.4	±1.5

Table 3. Retained Stability Result against Immersion Time

Polythene (%)	2-face Immersion Time (Day)						1-face Immersion Time (Day)					
	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	day0	day1	day2	day3	day4	day5
0	30100	28400	26500	23300	21350	18700	21000	20670	19740	18660	16210	11210
2	31200	32600	39200	30700	29400	27300	21630	21290	20332	19220	16696	11546
4	35400	36200	37900	36100	33600	31200	22661	22305	21301	20136	17492	12097
6	35990	36080	38010	40200	37980	34110	28977	27255	25740	24611	23225	14276
8	34300	34880	36010	35010	32.98	32160	26659	25074	23681	22642	21367	13134
10	28610	30680	32910	34700	29.98	27440	20832	20505	19582	18511	16080	11120

Table 4: Retained Strength Index (RSI) for Polyethene Modified Concrete

Polyethene Contents (%)	Immersion Time (Days) - 2Face						Immersion Time (Day) - 1Face					
	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5
0	100	94.35	88.04	77.41	70.93	62.13	100	98.4	94	88.9	77.2	53.4
2	100	98.4	95.71	94.23	87.5	79.59	100	98.4	94	88.9	77.2	53.4
4	100	98.06	97.79	94.92	93.4	88.14	100	98.4	94	88.9	77.2	53.4
6	100	99.75	94.92	94.55	94.76	94.78	100	99.1	98.8	94.8	80.4	69.3
8	100	98.34	97.97	96.15	95.25	93.76	100	98.1	94	88.9	80.2	53.4
10	100	95.91	95.43	93.25	86.93	82.45	100	94.4	88.8	84.9	77.2	49.3

Table 5. Swell Index (SI) of Modified concrete

2FACE							1FACE						
Immersion Time (Days)	0%	2%	4%	6%	8%	10%	Immersion Time (Days)	0%	2%	4%	6%	8%	10%
D0	0.05414	0.05408	0.05324	0.05216	0.05321	0.05332	**D0**	0.0674	0.0672	0.0670	0.0668	0.0671	0.0673
D1	0.05541	0.05539	0.05431	0.05325	0.05344	0.05364	**D1**	0.0679	0.0677	0.0676	0.0671	0.0673	0.0678
D2	0.05636	0.05596	0.05572	0.05407	0.05416	0.05441	**D2**	0.0727	0.0722	0.0722	0.0719	0.0724	0.0725
D3	0.05667	0.05616	0.05608	0.05552	0.05568	0.05554	**D3**	0.0786	0.0784	0.0782	0.0779	0.0781	0.0783
D4	0.05916	0.05857	0.05705	0.05646	0.05582	0.05566	**D4**	0.0846	0.0845	0.0841	0.0838	0.0840	0.0843
D5	0.05967	0.05923	0.05883	0.05979	0.06519	0.05741	**D5**	0.0905	0.0901	0.0899	0.0879	0.0896	0.0901

Variation of Retained Stability with Immersion Time at 6% Polyethene content for 2Face and 1F compaction

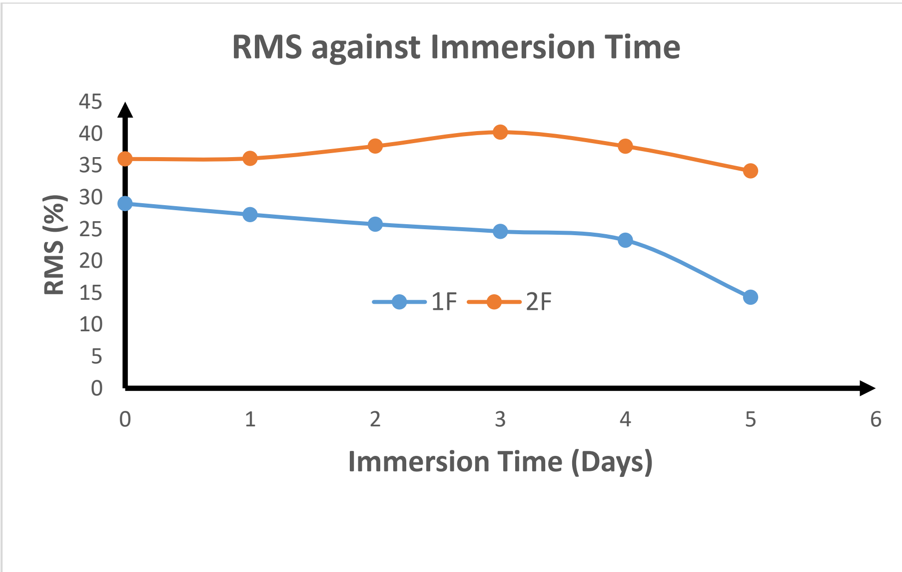

Fig 1: Graph of Retained Stability against Immersion Time for 1Face and 2Face Compaction

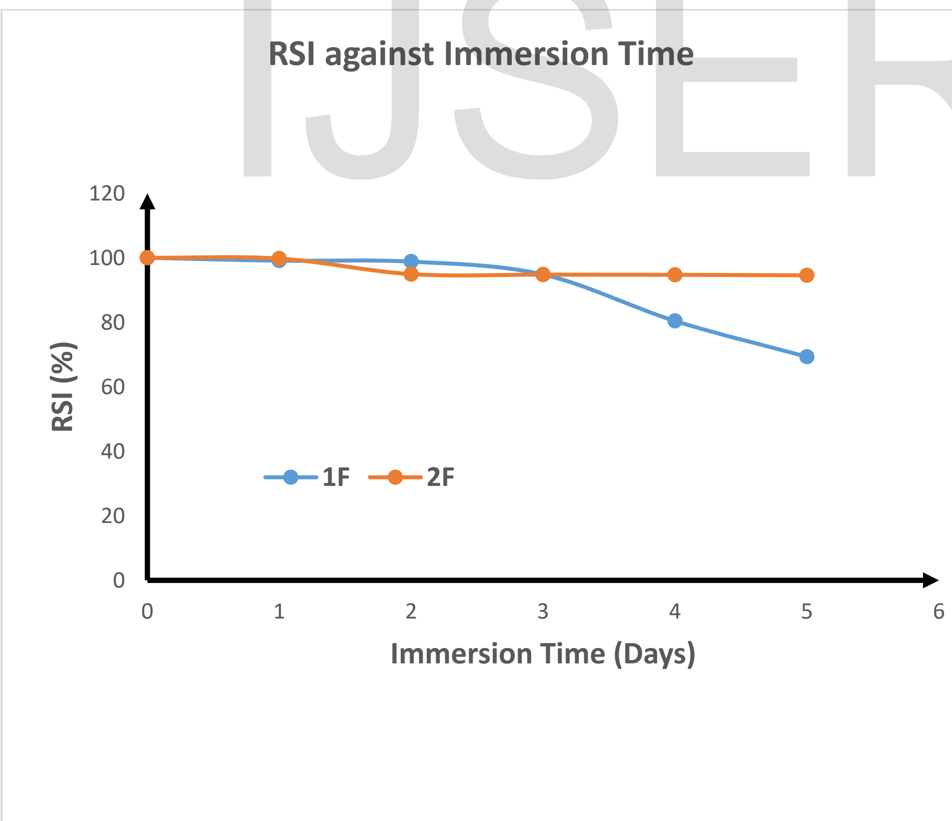

Fig 2: Graph of Retained Strength Index against Immersion Time for 1Face and 2Face Compaction

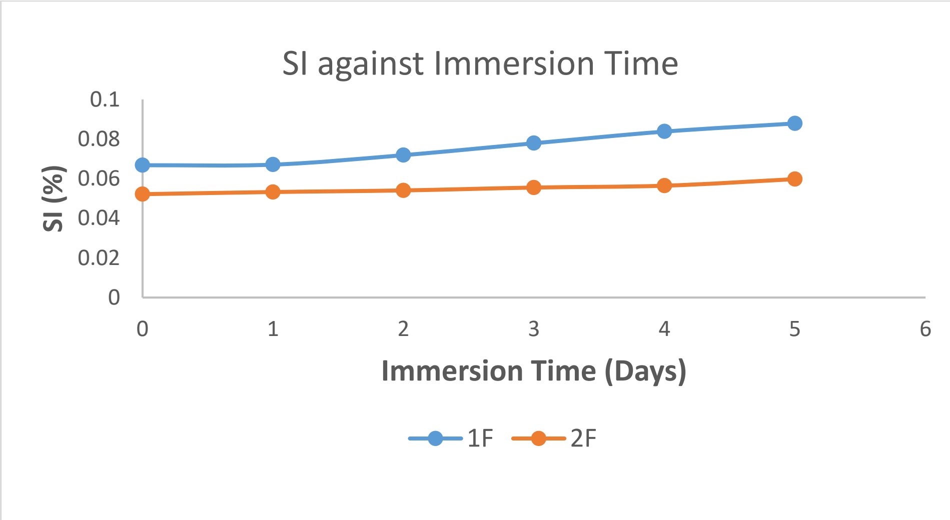

Fig 3: Graph of Swell Index against Immersion Time for 1Face and 2Face Compaction

4.0: DISCUSSION OF RESULTS

Retained Marshal Stability (RMS)

As illustrated **f**rom Table 3.0 and Figure 1.0 above, retained stability decreases rapidly with increase in immersion period as in asphalt concrete was submerged in the water**.** table 3.0 showed stability of the modified mixes decreased linearly with increasing soaking days and for all categories of soaking. It is seen that for the un-soaked mixes retained stability reduced in variation by 3% from 21000N for the unmodified mix (Day 0) to 20670N 19740N, 18660N, 16210N and 11210N respectively. The same trend was seen across all the other soaking days which caused a corresponding decrease in the stability of the modified asphalt concrete mix. The percentage difference between 1Face and 2Face in stability increases is 14.57%.

Retained Strength Index (RSI)

As illustrated in Table 4 and Figure 2, (RSI) values were decreases linearly with increase in immersion time. The reduction in the stability is as a result of moisture penetration of the concrete mix thereby reducing it durability. Retained strength index (RSI) of the modified mixes decreased linearly with increasing immersion time for all categories of immersion. Categorically The average percentage difference between 1F and 2F compaction using RSI result for the modified asphalt concrete is 8.7%.

Swell Index (SI)

Table 5 and Figure 2 shows the variation of swell across different soaking days for the unmodified and modified samples. For the soaked mixes, swelling index after one day of soaking was 3.1% for the unmodified mix. This indicates that addition of moisture causes a steady increase in the swelling of the asphalt concrete mix during the period of submergence. Categorically, for Day 0, the modified asphalt concrete single and double face compaction samples, SI decreased linearly then having percentage difference of 24%. Also, for day 1, day 2, 3, 4 and day 5, the percentage differences are 23%, 28.3%. 33.5%, 39 38% respectively. The average percentage difference for the 1F and 2F of the modified asphalt concrete is 31%

5.0: DEVELOPING CORRELATION BETWEEN I FACE AND 2 FACE COMPACTIONS

RMS CORRELATION

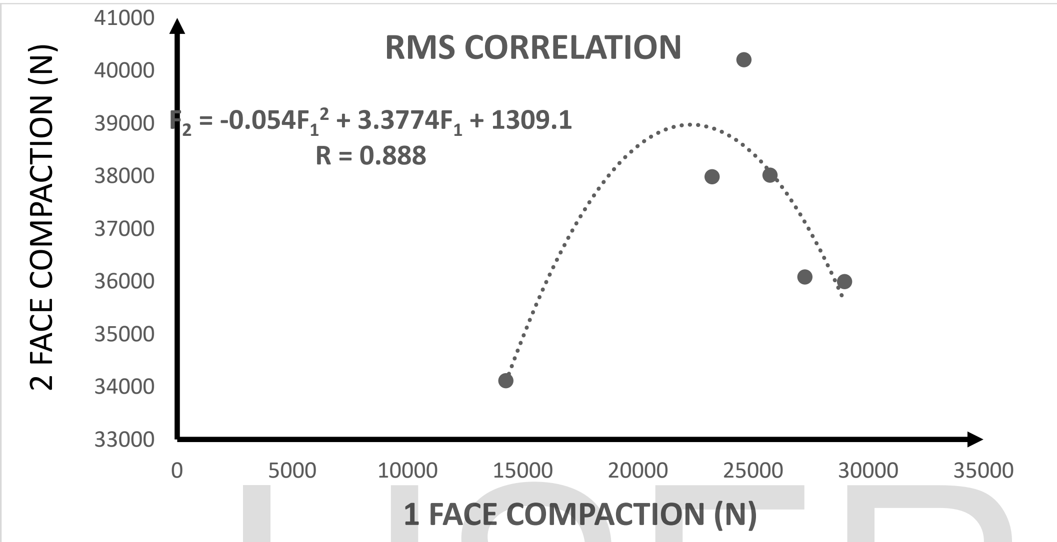

Fig 4: **Graph of RMS for 2Face and 1Face Compaction**

RSI CORRELATION

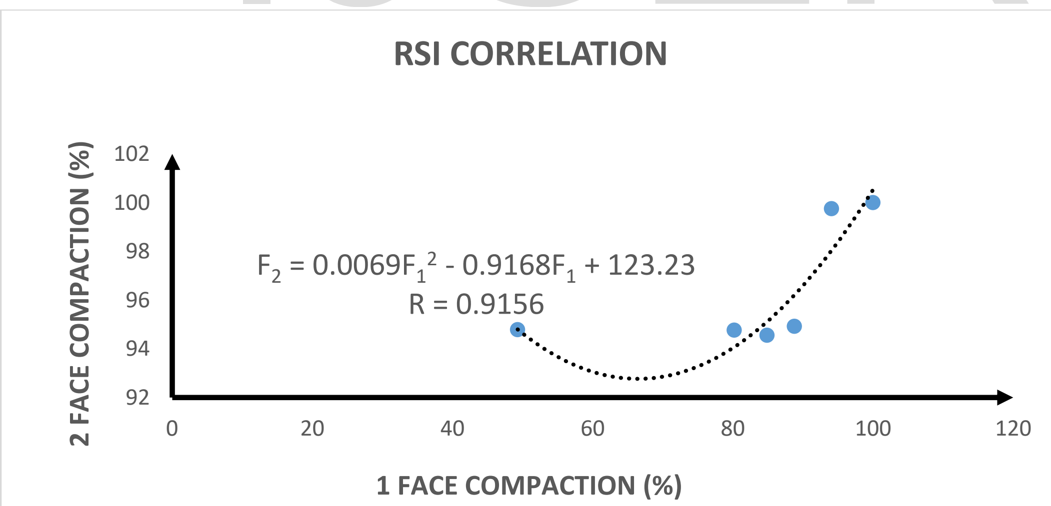

Fig. 5: Graph of RSI for 2Face and 1Face Compaction

SI CORRELATION

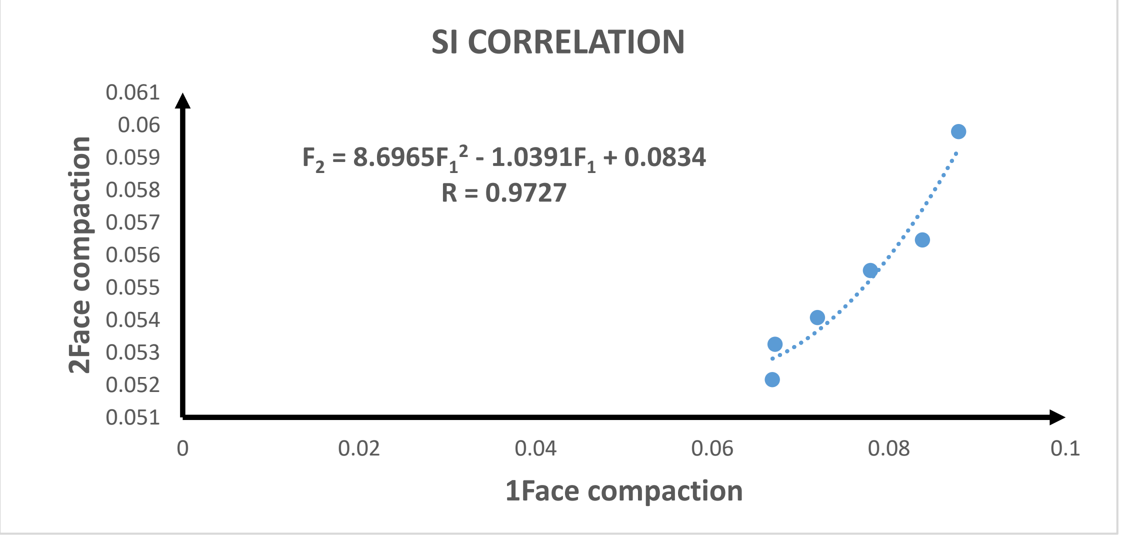

Fig 6: Graph of 2Face and 1Face Compaction for RMS

6.0: SUMMARY OF CORRELATION

Asphalt Concrete Properties	Model Equation	R
Retained Stability (N)	$F_2 = -0.054F_1^2 + 3.3774F_1 + 1309.1$	R = 0.888
Retained Strength Index	$F_2 = 0.0069F_1^2 - 0.9168F_1 + 123.23$	R = 0.9156
SWELL INDEX (%)	$F_2 = 0.0003F_1^2 - 0.0008F_1 + 0.0517$	R = 0.9183

REFERENCES

Al-Saffar, A. (2013). *The Effect of Filler Type and Content on Hot Asphalt Concrete Mixture Properties*. University of Mosul, College of Engineering.

Al-Tameemi A., Wang Y., Albayati A. (2016), Experimental study of the performance related properties of asphalt concrete modified with hydrated lime, Journal of Material Civil Engineering, 28(5) , 04015185-1.

ASTM. (2018). *Standard Terminology Relating to Materials for roads and Pavements.* West Conshohocken, PA.: ASTM International

.

Brown, E. R. and Foo, K. Y. (1989) „Evaluation of Variability in Resilient ModulusTest results‟ (ASTM D 41 23) National Centre for Asphalt Technology: Report No. 91-6.

Cabeza, L.F., Castell A., Medrano M., Martorell I., Pérez G., & Fernández I. (2010). Experimental study on the performance of insulation materials in Mediterranean construction. Energy and Building, 47: 630- 636

Igwe, E. A. (2015) "Contribution of Shredded Tire Chips as Filler Material on Stiffness of HMA Concrete. *Global Advanced Research Journal of Engineering, Technology and Innovation* (ISSN: 2315-5124) 4(5) 80-085.

Igwe, E. A., Ayotamuno, M. J., Okparanma, R. N., Ogaji, S. O. T. and Probert, S. D. (2009) "Road-surface properties affecting rates of energy dissipation from vehicle. *Journal of Applied Energy* 86(9) 1692–1696,

Igwe, E. A., Ekwulo, E. O. & Ottos, C. G. (2016) "Moisture Effect on Stiffness of Asphalt Concretes for Low Volume Roads: Comparative Study of Asphalt Institute and

Witczak 1-40D Models, *International Journal of Constructive Research in Civil Engineering* (IJCRCE) 2(4), 1-8.

Igwe, E.A amd Nyebuchi D.A. (2017) "Assess the Swell behaviour of HMA concrete subjection to heavy Traffic Loading" International Journal of Concrete Technology

Igwe, E.A., Ayotamuno, M.J., Okparanma, R.N., Ogaji, S.O.T., & Probert, S.D. (2009) 'Road Surface Properties affecting Rates of Energy Dissipation from Vehicles' *Journal of Applied Energy*, 86,1692-1696

Igwe, E.A., Ottos, C.G., & Ekwulo, E.O. (2016). "The role of candle wax as non-bituminous modifier in material re-characterization of bituminous concretes used synonymously for flexible pavement study on voids and flow".

Magdi (2014). An overview of moisture damage in asphalt mixtures. School of Civil Engineering, Engineering Campus, Universiti Saen Malaysia, March 2015.

Xiao, Papazian, H. S., (2007). The Response of Linear Visco-elastic Materials in the Frequency Domain with Emphasis on Asphaltic Concrete," *(1st) International Conference on the Structural Design of Asphalt Pavements*, pp. 454-463