INTERNATIONAL JOURNAL OF SUSTAINABLE CONSTRUCTION ENGINEERING AND TECHNOLOGY
Vol. 11 No. 4 (2021) 99-108

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IJSCET

http://penerbit.uthm.edu.my/ojs/index.php/ijscet
ISSN : 2180-3242 e-ISSN : 2600-7959

International Journal of Sustainable Construction Engineering and Technology

Quality Assurance in Testing of Highway Materials in Pakistan

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DOI: https://doi.org/10.30880/ijscet.2021.11.04.009
Received 08 May 2020; Accepted 28 December 2020; Available online 31 December 2020

Abstract: In Pakistan three modes of transportation are usually used. It is believed that road sector is the major source of transport, which carries about 92 percent of travelers and 96 percent of cargo traffic. There are various factors which may cause the deterioration of pavement such as inadequate drainage, frost action, unsatisfactory compaction and overloading etc. One of the important factors seriously affecting the pavement performance is quality of material. Although some research work has been carried out related to use of required quality materials in highway construction; however, limited research has been done related to quality assurance in testing of highway materials in commercial laboratories. As the approval of material usage mainly depends upon testing reports provided by laboratories, therefore poor quality assurance system of testing laboratories may have adverse effect on material approvals. Rapid growth of population in Pakistan demands expansions in highway constructions; therefore, assessment and improvement of quality assurance will ensure proper usage of required quality materials. In the above mentioned context assessment of few commercial laboratories involved in highway material testing was done in comparison to public sector laboratory. The results indicate that there are significant variations in test results carried out at different commercial laboratories. Based on the assessment the study highlights the improvement areas to raise the standard of quality assurance in highway material testing in Pakistan.

Keywords: Pakistan, quality assurance, material testing, national highways

1. Introduction

Pakistan's road network is vital for the movement of people and goods and plays an important role in integrating the country, facilitating economic growth and reducing poverty. As Pakistan's road sector is in developing stage and there seems to be less attention on quality assurance in testing of material quality which may result in poor performance of pavements. In Pakistan, the construction industry with quality issues has been fighting for many years. The construction cost can be reduced significantly when the construction industry adopts the concept of Quality Assurance and Quality Control (Khan et. al, 2008). In construction industry Quality Assurance plays an important role, it improves the quality of work at minimum cost. It helps to complete all project activities in the right way and time (Hendrickson, 1999).

Material quality assurance program includes sampling and testing, independent assurance testing, project materials certification, retention of sampling and testing records, verification of test procedures, calibration of testing apparatus

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and implementation of technical skills for personnel involved in materials sampling and testing (MDOT, 2010). Quality assurance involves many activities such as to develop a proper documentation, setup standards for the program, preparation of checklists, to manage the internal and external audits, analysis of failure modes and trainings related to program (NHAI, 2006). Quality Assurance includes regulation of the quality of raw materials, assemblies, products and components; services related to production; management, production and inspection processes. One of the main differences between Quality Control and Quality Assurance is that quality assurance is carried out before a project begins whereas quality control starts when the product is being manufactured. Thus, quality assurance is a dynamic process or proactively prevents defects and quality control is a corrective procedure for the determination of defects to correct them (Dange, 2009).

Douglas et. al (1999) did a research on the work of the California Department of Transportation, which had new Quality Control and Quality Assurance requirements for applying asphalt concrete. This approach to research and description of the projects has been included in the present study, used together with the recommendations and findings. Benson (2004) studied a process used by California to assess and implement innovative quality assurance practices for materials. The process involves three phases: a review of current practice, a structured evaluation of innovative methods and the planned development of a material management system. More than 1,600 performance data were identified and categorized by type of material. The practice of quality assurance for each item was found and critically reviewed on the basis of consistent failure.

Quality and safety are two of the most important topics to a project manager. Defects and failures can result in the cost and timeline of a project to be negatively affected. Quality assurance specifications are practical and realistic because they both provide a rational means for achieving the highest overall quality of the material or construction (James M. Newland, 2015). During construction of a highway, many tests are made for two purposes. First, to provide a permanent record evidencing that full value has been received for the monies expended on behalf of the taxpayer. Second, to make sure that unsatisfactory material or construction is not incorporated into the work. Engineering and testing consume a significant part of the total cost of highway construction, and the basic problem is how to best spend the testing monies to afford the greatest protection of quality (Quality Assurance Manual, 2019).

The literature related to quality assurance in testing of highway materials indicates that some research work has been carried out related to use of required quality materials in highway construction; however, limited research has been done related to quality assurance in testing of highway materials in commercial laboratories. Rapid growth of population in Pakistan demands expansions in highway constructions; therefore, this research has focused on assessment and improvement of quality assurance of laboratories involved in material testing is necessary to ensure required pavement performance.

2. Research Methodology

In order to achieve above mentioned research objective, procedure of some essential tests required in highway constructions was gathered. The checklists of different tests were also prepared. Selected essential tests were carried out in different commercial laboratories. Activities performed during the testing were compared with standard procedures.

2.1 Material and Tests Selected for the Research Work

Although there are various materials which are used for construction of highways such as fine aggregate, coarse aggregate and bitumen but the scope of this study was limited materials to coarse aggregate. Aggregate is inert (chemically inactive) material, which form the major part of the pavement structure and it is the prime material used in the road construction. Cost of coarse aggregate is around thirty percent of the total pavement cost in highway construction.

Aggregates can be either natural or artificially crushed and generally categorized as crushed stone, sand and filler. The quality, strength and durability of aggregates are critical in the design of asphaltic concrete. Some necessary properties of the road aggregate which should be ensured in highway construction are:

(i) Resistance to abrasion/Hardness.
(ii) Resistance to weathering action/Soundness.
(iii) Resistance to impact/Toughness.
(iv) Resistance to crushing/Strength.

The sample of coarse aggregate was obtained from a crusher plant situated near district Thatta, located in province Sindh, Pakistan. The following tests were selected for research work with respect to assessment of necessary properties

(i) Los Angeles abrasion test	(ASTM C131)
(ii) Aggregate soundness test	(ASTM C88)
(iii) Specific gravity & water absorption test	(ASTM C127)
(iv) Aggregate crushing value test	(BS 812 , PART 110)

In order to assess above mentioned tests, a checklist was prepared for each test based on standard procedure of ASTM and BS code. ASTM code was mostly preferred for each test whereas BS code is adopted for aggregate crushing value (Soomro, 2012).

2.2 Stepwise Research Methodology

Stepwise summarized methodology adopted in this research work is described below:
Step 1: Review of standard procedures of some essential tests required in highway construction:
Step 2: Selection of material
Step 3: Collection of material/sample from crushing plant
Step 4: Selection of tests for assessment of required material properties
Step 5: Preparing checklists for selected tests
Step 6: Test Results, Discussion and comparison in context of standard procedures
Step 7: Conclusions and recommendations based on results and discussion

3. Results and Discussion

The aggregate tests were carried out at four laboratories of Karachi and one laboratory of MUET, Jamshoro. Selected laboratories names were given from LAB 1 to LAB 5.

Based on prepared checklists, some points were observed during the testing of material. The analysis are presented in the form of tables and Fig.s. Table 1 to 6 show the analysis of different tests conducted in the selected laboratories to ensure the compliance of the testing procedure. The variations in the test results as well as the specified limits of tests are also shown in the foot note of tables. Fig. 1 (a) to Fig. 5 (a) portray graphical representation of test results whereas Fig. 1 (b) to Fig. 5 (b) indicate the reliability of each test with respect to the average value.

In order to show the reliability of test result an arrow is vertically drawn from the average value. The length of the arrow indicates the level of reliability with respect to standards. Larger the length of arrow less is the reliability of test result.

3.1 Los Angeles Abrasion Test (ASTM C131)

The results of Los Angeles Abrasion Test are portrayed in Table 1 and Fig. 1 (a), whereas Fig. 1 (b) shows the reliability of the test.

Table 1 - Result of Los Angeles abrasion test of coarse aggregate.

S #	Name of Lab	Code	Test Result	Mean (%)	S.D (%)	C.V	Max (%)	Min (%)	Range (%)	Difference From Mean Value	Remarks
1	LAB 1	ASTM C-131	30.60%	29	1.83	6	31	26	4.7	2.04%	The range of results is approximately 30% above Specified Limits
2	LAB 2	-do-	26.00 %							-2.56%	
3	LAB 3	-do-	30.70 %							2.05%	
4	LAB 4	-do-	27.50 %							-1.06%	
5	LAB 5	-do-	28.00 %							-0.56%	

Note: According to ASTM C-131, for Los Angeles Abrasion test the co-efficient of variation for multi laboratories should not be more than 4.5% whereas the results of multi laboratories tests should not differ from each other by more than 12.7% of their average value.

Hence, Maximum Range = 12.7/100*28.56 = **3.62 %**

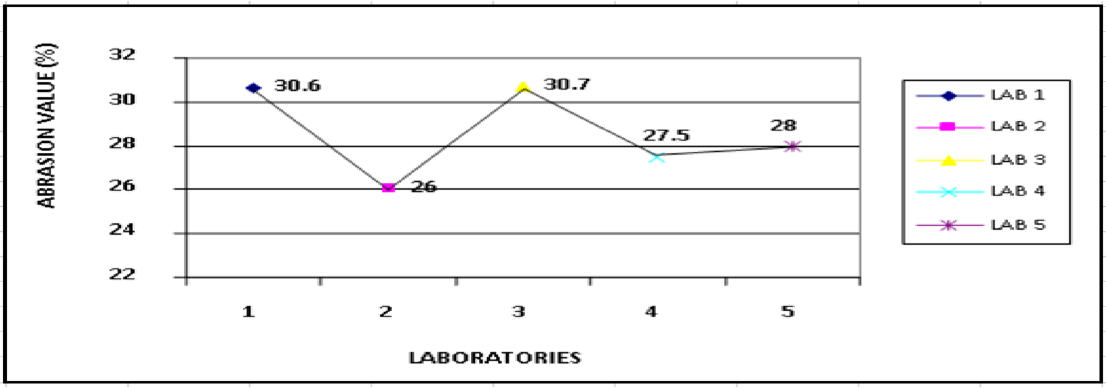

Fig. 1 (a) - Graphically representation of Los Angeles Abrasion test results.

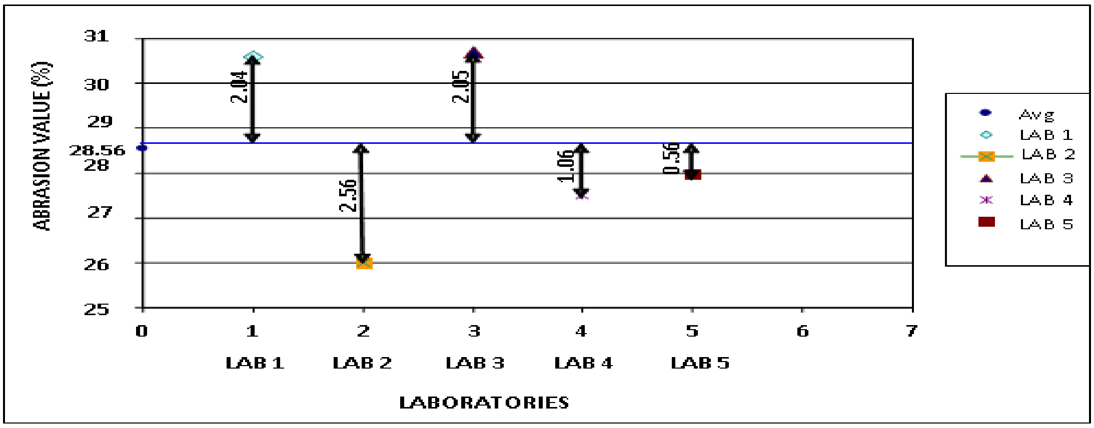

Fig. 1 - (b) Reliability of Los Angeles abrasion test result with respect to mean value.

During the Los Angeles Abrasion Test following points were observed:

(i) Out of five Los Angeles machines three were not properly working, their rpm was not according to the specified code. Two machines were not maintained properly, and it was observed that most of the material sample was lost from machines during testing process. One machine was extremely corroded and its rpm was lowest as compared to others. These points have affected the quality assurance of testing procedure of laboratory besides affecting the test results.

(ii) In case of Los Angeles test the fraction was taken as per specified in every laboratory except LAB 2. In LAB 2 larger size of aggregate was selected for the test and the sample was not split into smaller size as it was done in other laboratories. Consequently, the percentage loss of weight in LAB2 was found to be low as compared to others which was about 2.56% less than the average value.

(iii) In Los Angeles test the rpm of two machines in LAB 4 and LAB 5 were found to be less as compared to the standards. They were 25 and 28 rpm respectively whereas the standard rpm is 30-33. Consequently, the results observed were 0.5-1.5% less than average value.

(iv) In LAB 3 the rpm of Los Angles machine was greater as compared to the others and it was noted that the machine was revolved as per time and not as per specifies number of revolutions. Due to more rpm the no of revolutions of machine were not as per specified grading. Comparing the performed activities of LAB 1 and LAB 3, most of the activities are same but the difference in their result is 0.10% which is mainly due to the influence of rpm of machine.

(v) According to the code, in Los Angeles test the material passing through 1.70 mm sieve can be calculated by subtracting the retained material from total, but before applying that method retained material should be properly washed to remove fine particles. It has been observed that all the laboratories were doing the calculations without washing. Only in LAB 2 the material was properly washed and then calculation was done. This stated reason may also affect the accuracy of actual result.

(vi) Graphically representation of Los Angeles test shows that the range between results is 4.7 %, however as per standard it should not be more than 3.62 %. Looking at the comparison of the reliability in Fig. 1(b), the result of LAB 5 seems to be more reliable. Reliability of LAB 2 result seems to be low which is mainly due to noncompliance of proper material selection as observed during the research work.

3.2 Soundness Test (ASTM C88)

The results of Soundness Test are portrayed in Table 2(a) and Fig. 2 (a), whereas reliability of the test is depicted in Fig. 2(b).

Table 2 - (a) Result of soundness test of coarse aggregate.

S #	Name of Lab	Code	Test Result	Mean (%)	S.D (%)	C.V	Max (%)	Min (%)	Range (%)	Difference From Mean Value	Remarks
1	LAB 1	ASTM C-88	2.67%	3.16	1.14	36.1	5.36	2	3.36	-0.49%	The range of results is approximately 8% below Specified Limits.
2	LAB 2	-do-	2.00 %							-1.16%	
3	LAB 3	-do-	5.36 %							2.20%	
4	LAB 4	-do-	3.02 %							-0.14%	
5	LAB 5	-do-	2.76 %							-0.40%	

Note: According to ASTM C-88, for soundness test co efficient of variation for multi-Laboratories should not be more than 41% whereas the Range for multi laboratories should not exceed 116% of the average value.

Hence, Maximum Range = (116/100) x 3.162 = 1.16 x 3.162 = **3.66 %**

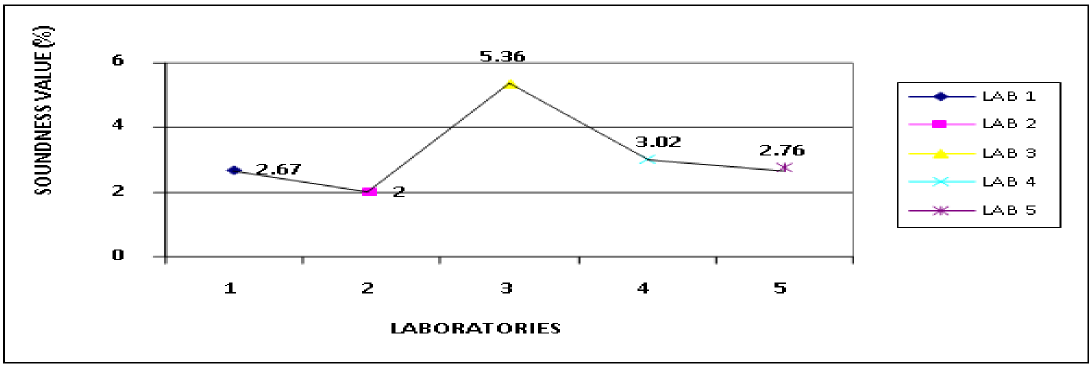

Fig. 2 - (a) Graphically representation of soundness test results.

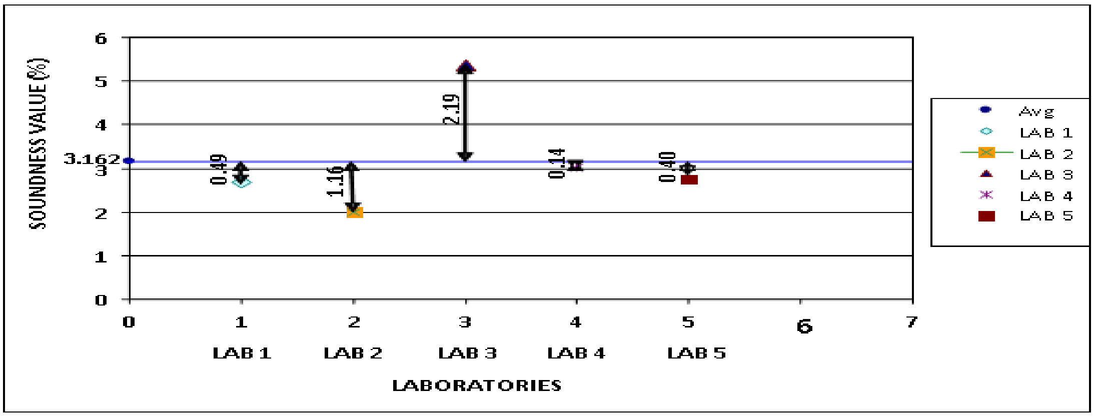

Fig. 2 - (b) Reliability of soundness test results with respect to mean value.

During the Soundness Test following points were observed:

(i) In soundness testing procedures at laboratories specific gravity of chemical and the temperature of water was not being noted at the time of preparation of solution. According to the code the specific gravity should be between 1.154 and 1.171 whereas the temperature should be maintained at 22°C. During the immersion of the sample in the solution of sodium sulfate the temperature was not being controlled in all the laboratories which should be 21±1°C.

(ii) In some laboratories the sodium sulfate used per liter of water was less as compared to the standard which should be minimum 350g per liter of water. The amount of chemical used per liter of water used in different labs is shown in table 2(b).

Table 2 - (b) Variation of % loss due to amount of chemical used.

S.No	Name of Laboratory	Aggregate Size	Chemical Used	% Loss
01	**LAB 1**	1 ½" – 1"	410 g/lit	3.48 %
02	**LAB 4**	1 ½" – 1"	250 g/lit	3.3 %
03	**LAB 2**	1 ½" – 1"	215 Lit	2.0 %

(iii) During the soundness test the sample should be covered to reduce the evaporation of water but this requirement was being ignored in laboratories except LAB 1 and LAB 4.

(iv) As per standard the result of soundness test should be the average of percentage loss of each fraction instead of taking sum of each fraction. It was observed that above process was done only in LAB 3 resulting in higher value of % loss.

(v) In soundness test a major cause of variation in test results is selection of fraction. Generally, the effect of solution on small particles is seen to be less as compared to larger particles. So the laboratories in which the small particles are added their soundness value seems to be less as compared to larger particles.

(vi) Graphically representation of soundness test indicates that the results of multi laboratories are in resemblance with each other except LAB 3 where a major non-compliance was observed in the calculation of result.

3.3 Specific Gravity and Water Absorption Test (ASTM C127)

The results of Soundness Test are portrayed in table 3 and Fig. 3 (a), whereas reliability of the test is depicted in Fig. 3(b).

Table 3 - Result of specific gravity test of coarse aggregate.

S.No	Name of lab	Code	Test Result	Mean (%)	S.D	Max(%)	Min(%)	Range(%)	Difference From Mean Value	Remarks
1	LAB 1	ASTM C-127	2.64	2.7	0.03	3	2.61	0.08	-0.02	The range of results is approximately 150% more than Specified Limits
2	LAB 2	-do-	2.61						-0.05	
3	LAB 3	-do-	2.68						0.02	
4	LAB 4	-do-	2.69						0.03	
5	LAB 5	-do-	2.68						0.02	

Note: According to ASTM C-127, for Specific gravity test value of Standard Deviation for Multi laboratories should not be more than 0.011 whereas the Range for Multi-Laboratories should be less than 0.032.

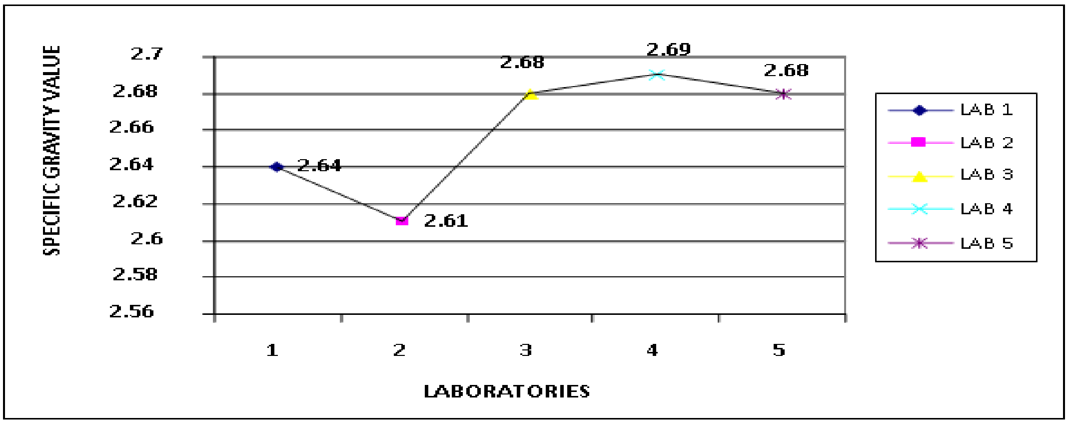

Fig. 3 - (a) Graphically Representation of Specific Gravity test results

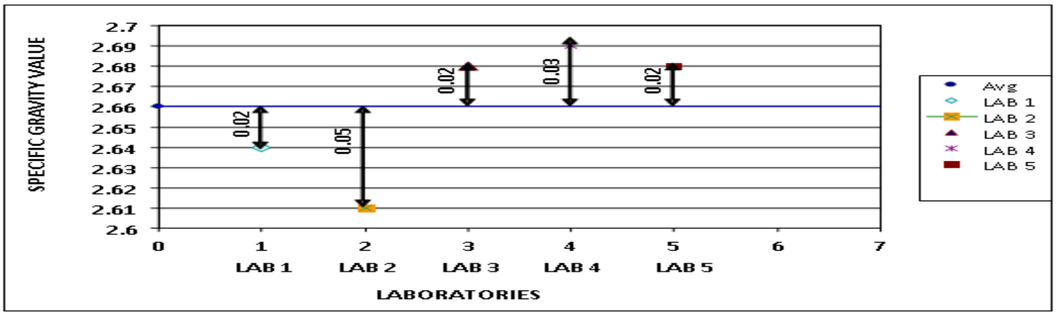

Fig. 3 - (b) Reliability of specific gravity test results with respect to mean value

The results of Water Absorption test are portrayed in table 4 and Fig. 4 (a), whereas reliability of the test is depicted in Fig. 4(b).

Table 4 - Result of Water absorption test of Coarse Aggregate

S.No	Name of Lab	Code	Test Result	Mean (%)	S.D (%)	Max (%)	Min (%)	Range (%)	Difference From Mean Value	Remarks
1	LAB 1	ASTM C-127	0.76%	0.516	0.1966	0.8	0	0.43	0.26%	The range of results is approximately 5% above the Specified Limits
2	LAB 2	-do-	0.33 %						-0.17%	
3	LAB 3	-do-	0.40 %						-0.10%	
4	LAB 4	-do-	0.75 %						0.25%	
5	LAB 5	-do-	0.34 %						-0.16%	

Note: According to ASTM C-127, for Water absorption test value of Standard Deviation for Multi laboratories should not be more than 0.145% whereas the Range for Multi -laboratories should be less than 0.41%.

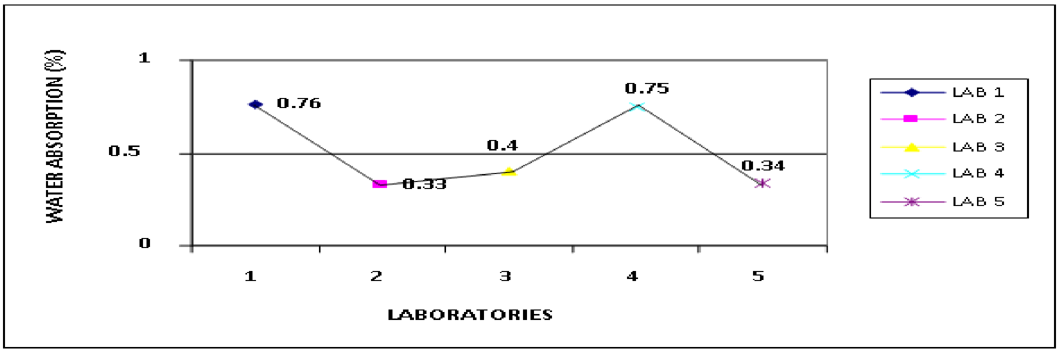

Fig. 4 (a) Graphically Representation of Water absorption test results

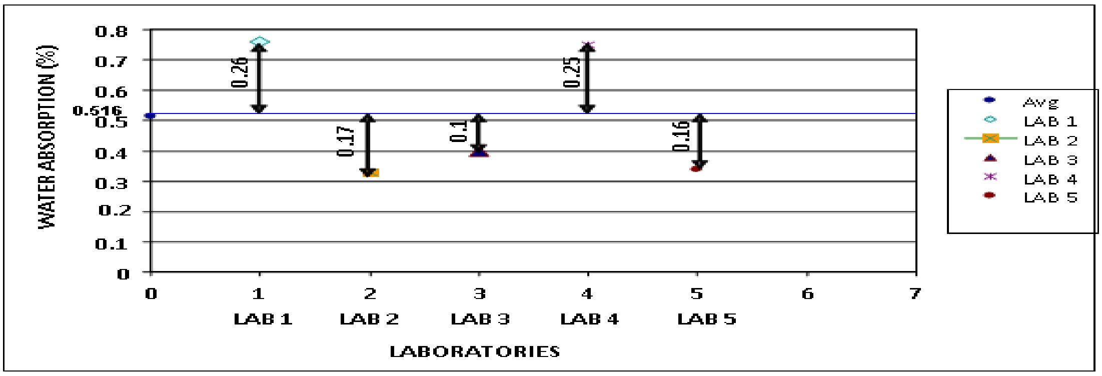

Fig. 4 - (b) Reliability of water absorption test results with respect to mean value.

During the Specific Gravity & Water Absorption Test following points were observed:

(i) During the specific gravity test every laboratory taken different sizes of sample. In LAB1 and LAB3 the larger size particles were taken for the test resulting in higher water absorption as compared to other laboratories. Generally larger particles absorb more water as compared to small particles.

(ii) In specific gravity test the temperature of water was not being controlled during measuring the weight of sample. As per standard procedure requirements it should be maintained at 23 $\pm$ 1°C.

(iii) Graphical representation of specific gravity test shows that there is high variation between the results of multi laboratories. The observed range is around 150 percent more than specified limits.

3.4 Aggregate Crushing Value Test (BS 812, PART 110)

The results of Aggregate Crushing Value test are portrayed in table 5 and Fig. 5 (a), whereas reliability of the test is depicted in Fig. 5(b).

Table 5 - Result of crushing value test of coarse aggregate.

S #	Name of Lab	Code	Test Result	Mean (%)	S.D (%)	Max (%)	Min (%)	Range (%)	Difference From Mean Value	Remarks
1	LAB 1	BS 812, Part 110	27.73%						3.46%	
2	LAB 2	-do-	22.40 %						-1.87%	
3	LAB 3	-do-	24.70 %	24.27	2.7	27.7	20.18	7.55	0.43%	The range of results is within Specified Limits
4	LAB 4	-do-	20.18 %						-4.09%	
5	LAB 5	-do-	26.33 %						2.06%	

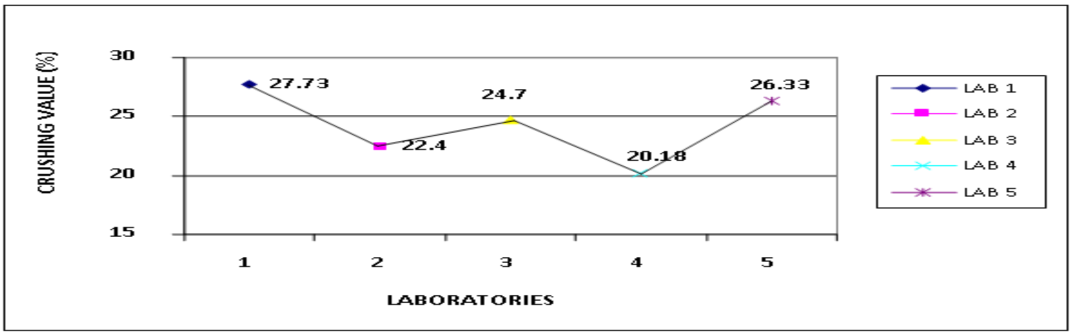

Fig.5 - (a) Graphically representation of aggregate crushing value test results.

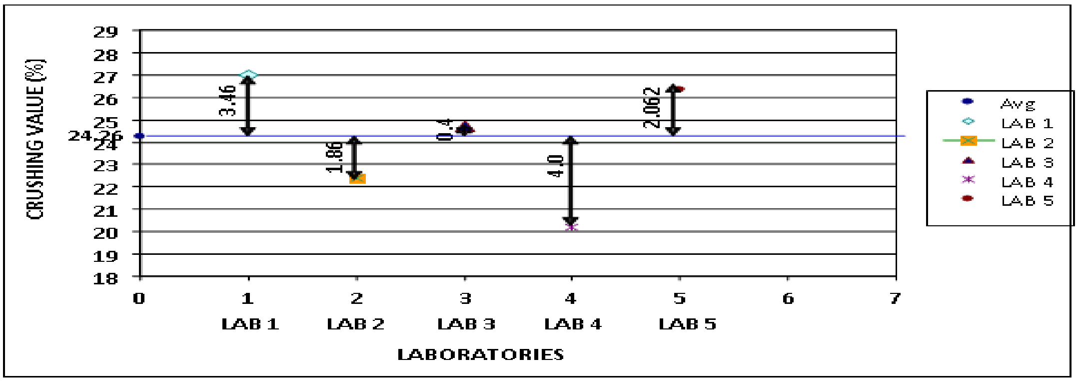

Fig. 5 - (b) Reliability of aggregate crushing value test results with respect to mean value.

During the Aggregate Crushing Value Test following points were observed:

(i) In crushing value test, the Measuring Cylinder was not used in every laboratory except LAB 1 and LAB 2, consequently the material taken for the test did not bear resemblance to the material obtained from the measuring cylinder.

(ii) Load of 400KN in 10 minutes was only applied in LAB 1 and LAB 2; whereas in other laboratories non-compliance to above standard requirement was observed.

(iii) About 50% of compression machines used for testing of crushing value were older models; therefore, the platens of the machine were difficult to set in order to apply the uniform load on the sample. During the research it was also observed that majority of the technicians were not fully aware of the standard testing procedures.

4. Conclusion and Recommendations

In order to ensure the quality of commercial laboratories a number of tests were conducted at selected laboratories. Material to carry out selected tests was obtained from the crusher plant near Thatta, Pakistan. Based on the laboratory results test results it is concluded that most of the test results are outside the specified similarity range although the material and procedure of testing carried in different laboratories was same. Out of four tests only one test i.e. aggregate soundness test is within specified similarity range of the multi laboratory limits; whereas as all others test are beyond multi laboratory test conduct limits. The findings indicate poor quality assurance of testing procedures in commercial testing. It was also observed that one laboratory out of five laboratories considered in this study follow the activity of quartering which is a basic requirement for the quality assurance of many tests. In addition, most of the laboratories do not follow the standard procedure in selection of fraction size. Although all the laboratories considered in this study were following the standard code of ASTM; however, some of important activities were not complied which is one of the main reasons of variation in test results conducted at different laboratories. Another reason of variation in test result was the difference of equipment condition with laboratories and comparative standard requirement. Corrosion of equipment, material slippage, poor level of equipment calibration, difficult in setting the platens were the main reasons of poor quality assurance and variation in test results. The results of this study are based on the observations of different test carried out in commercial laboratories. The results indicate that there are significant variations in test results carried out at different commercial laboratories. Based on the above assessment it is concluded that there is an immense need to improve the quality assurance in highway material testing in Pakistan. It is recommended that the testing work should be carried on the basis of non-complied activities in order to further observe the effect of non-complied activities on the test. Proper training of the technicians employed in commercial laboratories is also essential in improving the adoption of standard procedures. In addition, a proper regulatory framework should be adopted by relevant public sector departments for ensuring quality assurance in testing of highway materials.

Acknowledgement

The authors highly acknowledge the support of Civil Engineering Department and Directorate of Postgraduate Studies Mehran University of Engineering & Technology Jamshoro Pakistan in carrying out this research work.

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