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All corresponds should be addressed to:

Editor in Chief - Journal of Engineering and Technology
Faculty of Engineering Technology
The Open University of Sri Lanka
Nawala
Nugegoda
Sri Lanka

Telephone: +94112881314, email: nssen@ou.ac.lk

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Effects of Three-Wheeler Parks near Intersections

U. A. Gopallawa and K. S. Weerasekera*

Department of Civil Engineering, The Open University of Sri Lanka, Nugegoda, Sri Lanka

*Corresponding Author - email: kolitaw@gmail.com, Tele: +94112881433

Abstract – *This paper presents results of recent research findings of the consequences of parked three-wheelers on approaches to busy road intersections. Three-wheeler is a popular mode of transport, and hiring them has become a self-employment mean in Sri Lanka. Three-wheeler operators obtain legally designated parking areas from the municipal councils or urban councils. Municipal councils and urban councils are in the practice of permitting three-wheelers to legally park near road intersections of congested city/town roads. This study investigates some effects on traffic flow due to parked three-wheelers near road intersections.*

Five road intersections which had three-wheeler parks nearby were selected from Kandy, Matale and Kotte municipal council areas in Sri Lanka, traffic surveys were conducted, and data analyzed. From the analyzed data, it was seen that an increase in average delay of minor road vehicles entering the major road resulting a decrease in exit rate of vehicles from minor road due to three-wheeler parks located near road intersections. Hence, it was seen that three-wheeler parks near road intersections do have some negative effects on traffic flow. Information relating to accidents over the years near the selected road intersections were collected from relevant respective police stations. The results showed that there is an increase of accidents after implementing three-wheeler parks near road intersections.

This study stresses the deficiencies of currently adopted practice of improper location of three-wheeler parks near road intersections and its negative impacts. It also suggests new rules and regulations that could be developed as a suitable tool to minimize such harmful effects on traffic flow at road intersections.

Keywords: *Exit Rate, Average Delay, Tanner's Model, Three-wheelers, Trishaw Taxis*

Nomenclature

q_1 - arrival rate on major road (veh/s)
q_2 - arrival rate on minor road (veh/s)
β_1 - minimum following time of major road vehicles (s)
β_2 - Move – up time of minor road vehicles (s)
q_p - the major (priority) stream volume (veh/s)
t_f - the follow– up headway (s)
t_a - the critical acceptance gap (s)
C - the exit rate from minor road (veh/h)

1 INTRODUCTION

Three-wheelers have rapidly become a popular mode of transport in Sri Lanka during last three decades. This mode of transport became more popular due to its free availability, less road space occupation, low travel and maintenance cost hence its economic benefits (Gordon, 1985 and Kumarage et al., 2010). Due to these reasons and its comparative low purchase cost, people are tempted to purchase or hire three-wheelers for their day to day travel. The annual growth rate of three-wheelers is 15.4% (Dept. of Motor Traffic, 2011).

Three-wheelers are commonly used for hiring purposes as an alternative for taxies in Sri Lanka. Three-wheeler operators obtain assigned parking areas from the municipal councils or urban councils. It could be seen that municipal councils and urban councils are in the practice of permitting three-wheelers to park near road intersections of congested city/town roads based on three-wheeler owners' requests.

This leads to visibility obstruction at intersections, reduce road capacities by bottle-necking the approaches of the intersection, causing inconvenience to both pedestrians and drivers, affecting the smooth flow of traffic at the intersection. Finally this leads to a reduction in passing through the intersection, and may also increase accident threat at these locations (Weerasekera, 2008).

Through this study, it is expected to investigate any negative effects on average delays and exit rates of minor road vehicles, and accident effects at the location due to three-wheeler parks located near road intersections.

Five road intersections from three municipal council areas were selected for the study (Fig. 1). These study locations were selected in such a way that they had no external effects other than the direct effect due to the presence of three-wheeler parks near road intersections.

2 AIM AND OBJECTIVES

The aim of this study is to investigate effects of three-wheeler parks near road intersections.
To achieving the above aim, some objectives have to be satisfied. Hence the objectives of the study are to find the effects of three-wheelers parking near road intersections by paying attention to following.

- Selection of five three-wheeler parks located near road intersections in congested cities Kotte, Kandy, and Matale municipal council areas.
- Collect information from the police stations about the accidents near the road intersections before and after implementing three-wheeler parks at those locations.
- Collect information regarding the practice adopted by municipal councils in allowing three-wheeler parks, regulations or guidelines, which they adhere when permitting three-wheeler parks.
- Conducting vehicular traffic surveys and a study of traffic flow patterns at each location to observe effect for absorption capacities and average delays for vehicles.
- Analyzing the results and quantifying the effects.
- Suggest the conclusion and any recommendations for effective three - wheeler parks.

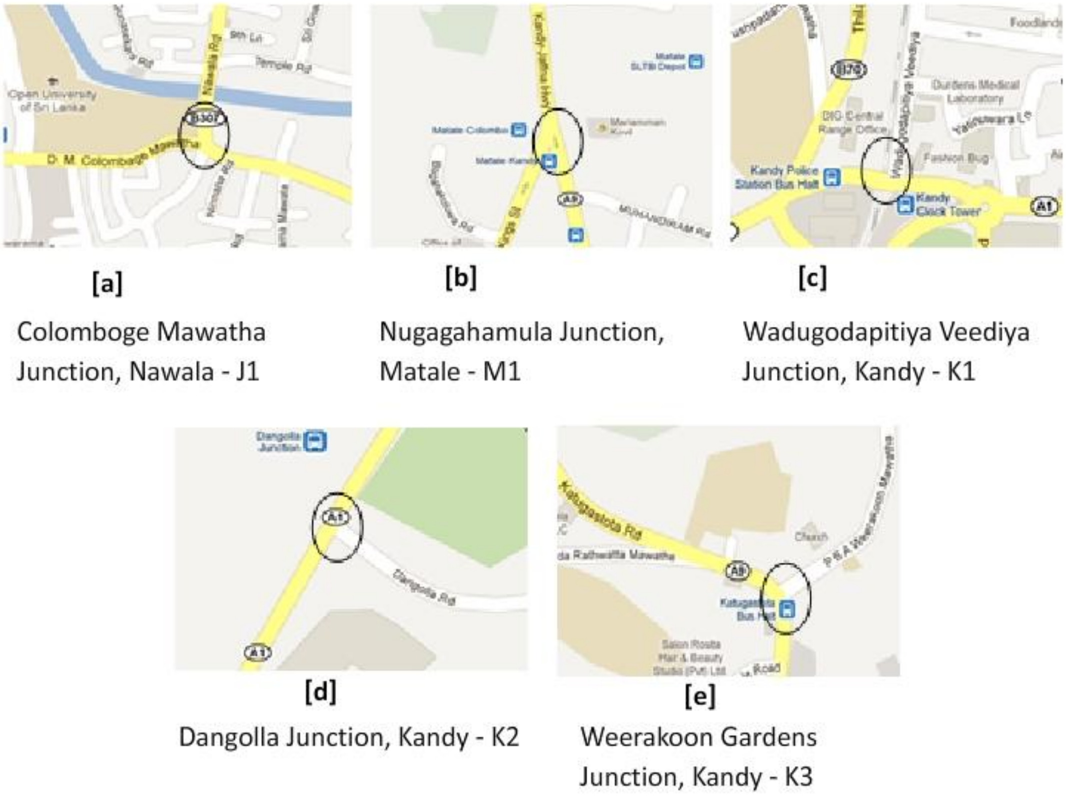


Fig. 1 Selected study locations

3 LITERATURE REVIEW

3.1 Accident Studies

By observing past accident records at the vicinity, the crash patterns at an intersection or on a roadway segment can be identified. Properly executed accident studies will help to know the basic causes of the accidents and to take preventive measures to eliminate them.

Road accidents can be grouped to following four accident types as follows (Wets, 2003):

- *Fatal Accidents*: Fatal accident is an accident in which death of one or more persons. A fatal accident is defined as an accident where deaths occurred within 30 days of the accident.
- *Serious Injuries*: Serious injury accident is an accident in which one or more persons are seriously injured and partial or permanent disability to the victims.
- *Injuries*: Injury accident is an accident in which victims has gone through medical treatment but not admitted to the hospital.
- *Property damages*: A non injury accident is an accident in which no one is killed or injured but which results in damage to the vehicle/s and/or other property only.

Wests (2003) has assigned weightages of 5, 3, 2 & 1 for above different types of accidents which this study too has adopted.

3.2 Tanner's Model

J. C. Tanner developed a model in 1962, which can use to calculate the average delay and exit rate at an uncontrolled intersection. Tanner has made a theoretical analysis of an unsignalised intersection governed by the priority rule under the following assumptions (Tanner, 1962).

- Vehicles on the major road arrive at the intersection at random at a rate q_1 per unit time and pass through at intervals of not less than β_1.
- Vehicles on the minor road arrive at random at a rate q_2 and pass through at intervals of not less than β_2.
- Vehicles on the major road cannot enter the intersection within a time α ($\alpha>\beta_1$) after the passage of the last major road vehicle. In other words, one minor road vehicle can pass through headway of duration between α and $\alpha+\beta_2$ in the major road traffic, two can pass in a headway of between $\alpha+\beta_2$ and $\alpha+2\beta_2$, etc.

3.2.1 Exit Rate from Minor Road (C)

Exit rate is the maximum possible flow (or arrival rate) that can enter or cross a major flow from a minor approach such as the leg of a T-intersection or from a driveway to a reasonable level of pedestrian density (Weerasekera *et al.,* 1997). The exit rate (C), the number of vehicles per hour in a minor stream that can enter a major stream, calculated using the following equation which was originally developed by Tanner (1962).

$$C = 3600\frac{q_p e^{(-q_p t_a)}}{1 - e^{(-q_p t_f)}}$$

Where, C = the exit rate from minor road
q_p = the major (priority) stream volume in veh/sec
t_a = the critical acceptance gap in seconds
t_f = the follow-up headway in seconds

3.2.2 Average Delay (w_2)

Average delay is the average time a driver is expected to spend at a driveway or approach road waiting to enter the main stream of vehicles on the major road. It is a function of the major road flow and it is also influenced by the nature of the headway distribution on the major road (Tanner, 1962). Tanner's formula for the average delay (w_2) to minor road vehicles due to the vehicles on the major road, when the system is in statistical equilibrium was used to calculate average delay at each intersection is as follows.

$$\overline{w_2} = \frac{1/2E(y^2)/Y + q_2 Ye^{(-\beta_2 q_1)}[e^{(\beta_2 q_1)} - \beta_2 q_1 - 1]/q_1}{1 - q_2 Y[1 - e^{(-\beta_2 q_1)}]}$$

Where,

$$Y = E(y) + 1/q_1$$

$$E(y) = \frac{e^{[q_1(t_a - \beta_1)]}}{q_1(1-\beta_1 q_1)} - \frac{1}{q_1}$$

$$E(y^2) = \frac{2e^{[q_1(t_a-\beta_1)]}}{q_1^2(1-\beta_1 q_1)^2} e^{[q_1(t_a-\beta_1)]} - t_a q_1(1-\beta_1 q_1) - 1 + \beta_1 q_1 - \beta_1^2 q_1^2 + \frac{\frac{1}{2}\beta_1^2 q_1^2}{(1-\beta_1 q_1)}$$

q_1 = arrival rate on major road

q_2 = arrival rate on minor road

β_1 = minimum following time of major road vehicles

β_2 = move-up time of minor road vehicles

t_a = critical acceptance gap

4 METHODOLOGY

4.1 Accident Study

Information about the accidents occurred before and after implementing three-wheeler parks at each location was collected from respective police stations. Types of accidents were property damages, minor injuries, serious injuries and fatal accidents.

4.2 Procedure adopted by Municipal Councils

Procedure adopted by municipal councils for permitting three-wheeler parks near road intersections was studied and indicated in Fig. 2, based on the information collected from the three municipal councils.

It was clear that the relevant authorities have not considered the affect on pedestrian safety, vehicular flow, and reduction of carriageway widths when permitting the three-wheeler parking areas near road intersections.

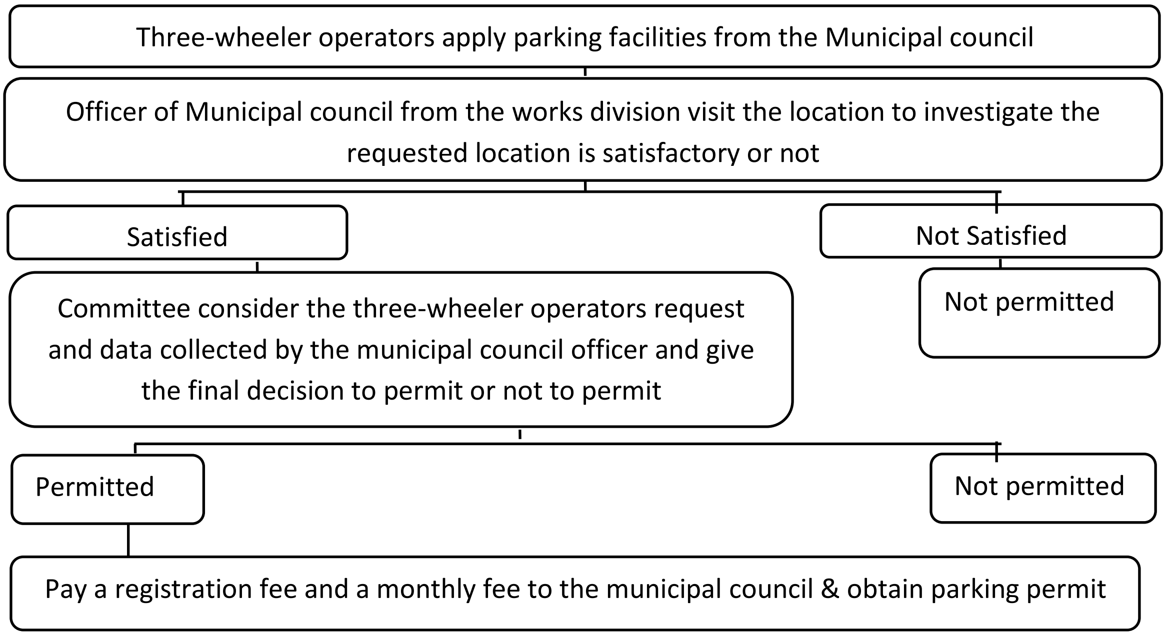


Fig. 2 Procedure adopted for permitting three-wheeler parks

4.3 Traffic Surveys

Traffic surveys were conducted for a period of three hours (at each location) with moderate to heavy traffic and parked three-wheelers, to study the impact on traffic flows at selected study locations. Data were collected to investigate any effects of parking of three-wheelers near road intersections on the traffic flow, such as effect on average delay for the vehicles entering from minor road to the major road, and the effect on exit rate of the minor road.

- The numbers of vehicles in traffic flows of major and minor roads were collected. All the counts were recorded at 5 minutes intervals using automatic traffic counters coupled with pneumatic rubber tubes.
- Time headways of adjoining vehicles within different bunch of vehicles along major road were noted. The number of vehicles which were included in each bunch was also counted. This was carried out for 100 samples at each location. Then the average time headway gives the minimum following time of major road vehicles (β_1).
- Number of vehicles which entered the major road from the minor road was recorded for period of three hours at each location. Counts were done in 5 minutes intervals.
- Vehicle registration number of each vehicle and the time joining the minor road queue were recorded. Also the vehicle registration number of each vehicle and the time when vehicles entered to the major flow were recorded (Fig. 3). The difference of the above mentioned times were used to find the delay of each vehicle at the intersection.
- Number of three-wheelers parked in the study location was recorded at each 5 minutes interval.

Fig. 3 Conducting manual traffic counts

5 DATA ANALYSIS

5.1 Analysis of Accident Data

Statistical analysis was carried out to compare accidents that have occurred before and after implementing three-wheeler parks near each road intersection. For this analysis weightages of 5, 3, 2 and 1 were assigned for fatal, serious injuries, injuries and property damages respectively (Wets, 2003). Weightages of accidents for K2 study location is shown in Fig. 4.

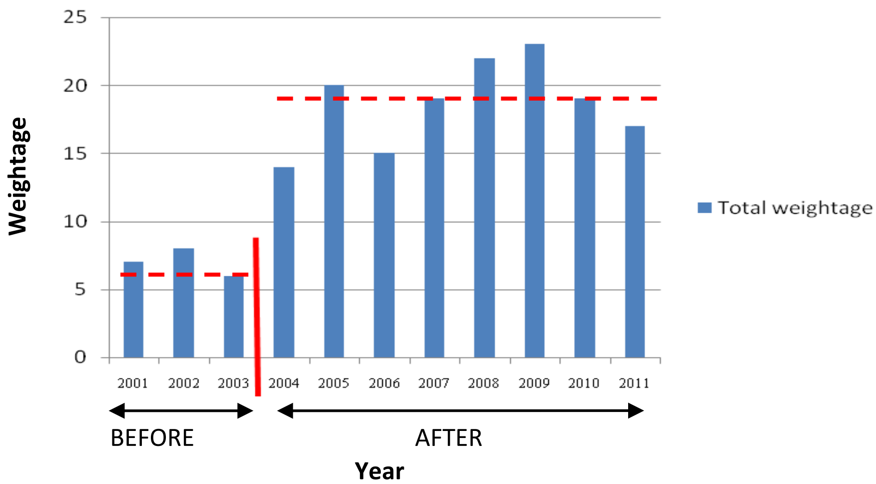


Fig. 4 Total weightage of accidents at K2 study location

Total weightages of accidents with three-wheeler parks in K1, K3, and M1 study locations represent in Appendix A. Fig. 4 and Appendix A indicate that there is a clear jump of average of weightages of accidents before and after implementing three-wheeler parks near K1, K3, M1 and J1 study locations. After implementing three-wheeler parks there is an increase of accidents at each location. According to the police accident records at K1, K2, K3, M1 and J1 most of the accidents occurred due to the following reasons.

- Visibility obstruction near the road intersection due to the three-wheelers parking.
- Increasing conflicting movements by reducing the road capacity and indiscipline of three-wheeler operators.
- Obstructing the pedestrian's walking paths.

According to the above observations vehicle accidents were not due to the increase of traffic flow. The accidents were occurred due to the implement of three-wheeler parks near road intersections by visibility obstruction, increase of conflict movements and obstructed pedestrians' walking ways.

5.2 Exit Rate and Average Delay Analysis

5.2.1 Exit Rate of Minor Road Vehicles

The information obtained from the traffic surveys were used to calculate exit rates of minor road vehicles.

- The exit rate of minor road vehicles, is the number of vehicles per hour in a minor stream that can enter a major stream. This is calculated using the Tanner's model described earlier.

Specimen calculation:

Sample calculation for exit rate of minor road in 3:00 pm – 3:05 pm time interval for J1 study location

$$q_p = \frac{177}{5\ x\ 60} = 0.59vps$$

$$t_f = 3seconds, \qquad t_a = 5seconds$$

$$C = 3600\frac{q_p e^{(-q_p t_a)}}{1 - e^{(-q_p t_f)}}$$

$$C = 3600\frac{0.59e^{(-0.59\text{x}5)}}{1 - e^{(-0.59\text{x}3)}}$$

$$C = 133.71vph$$

$$\text{Exit rate from minor road} = \frac{11\ x\ 60vph}{5} = 132vph$$

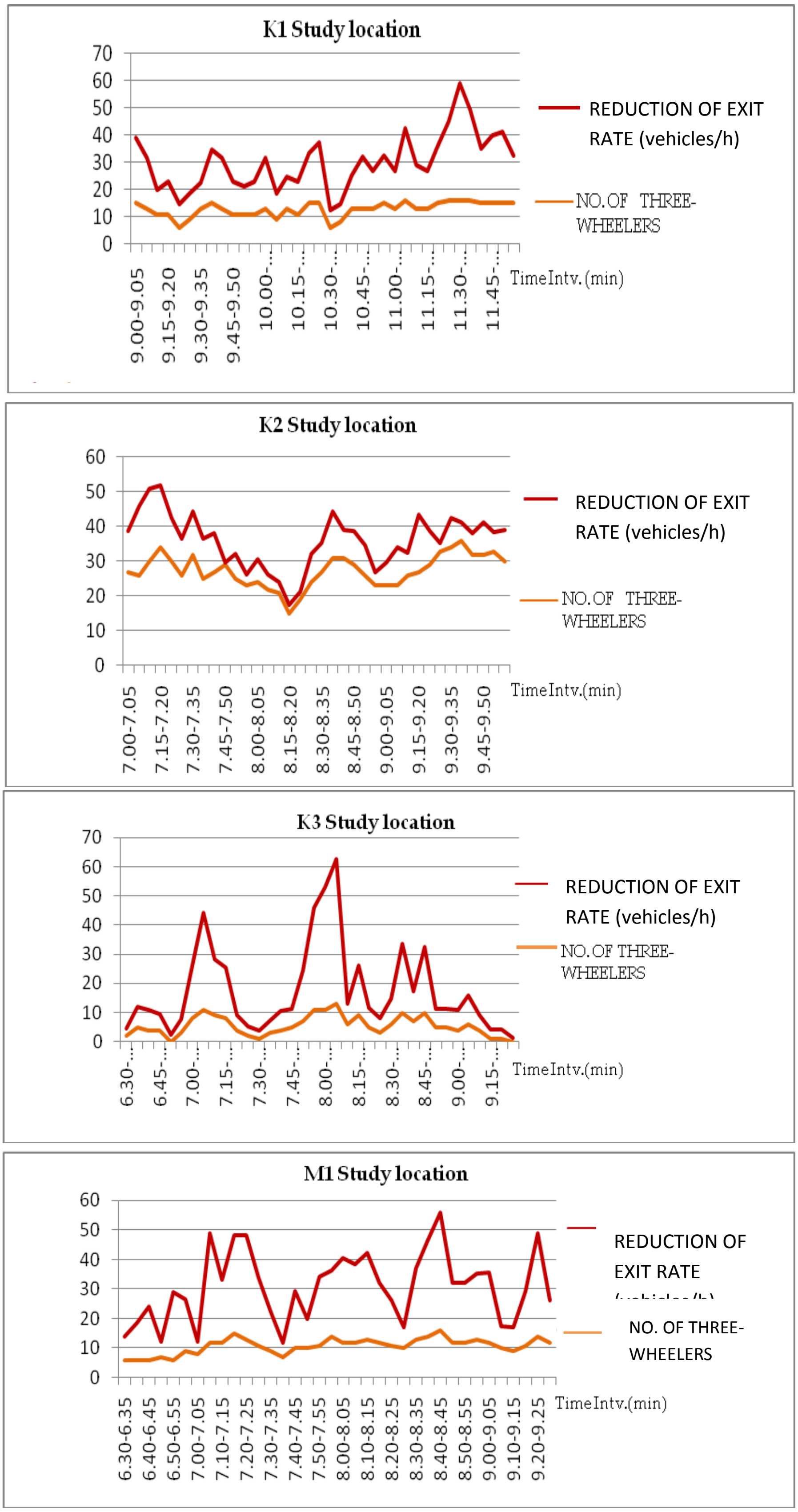


Fig. 5 Effect on the exit rate

According to the above results there is a considerable effect on the exit rates of minor road vehicles. In each study location, when the number of three-wheelers increased the reduction of exit rate was also increased.

5.2.2 Average Delay

The information obtained from the traffic surveys were used to calculate average delays.

- Average delay (w_2) to minor road vehicles due to the vehicles on the major road, when the system is in equilibrium was used to calculate average delay at each intersection is as follows (Tanner, 1962; Weerasekera *et al.*, 1997).

Specimen calculation:

Sample calculation for average delay, 3:00 pm - 3:05 pm time interval for J1 study location.

$$\beta_1 = \frac{Total\ following\ time}{Total\ \ sample}$$

$$\beta_1 = 1.12\ seconds \qquad \beta_2 = 3\ seconds$$

$$q_1 = \frac{177}{5 \text{ X } 60} = 0.59vps$$

$$q_2 = \frac{21}{5 \text{ X } 60} = 0.07vps$$

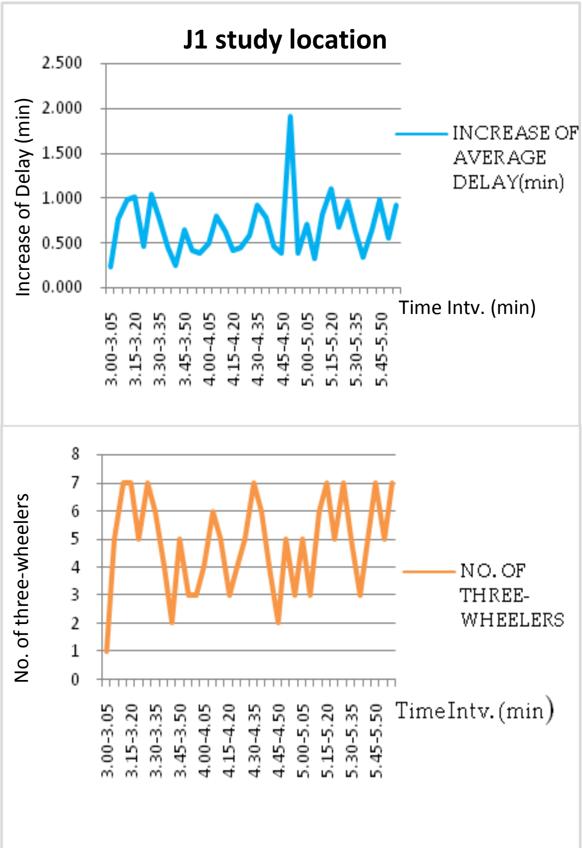
$$\overline{w}_2 = \frac{\frac{1}{2}\left(\frac{4316.8029}{49.375}\right) + 0.07\text{x}49.375e^{-3\text{x}0.59}[e^{3\text{x}0.59} - 3\text{x}0.59]/0.59}{1 - 0.07\text{x}49.375[1 - e^{-3\text{x}0.59}]}$$

$$\overline{w}_2 = 0.417619min = 25.05713seconds$$

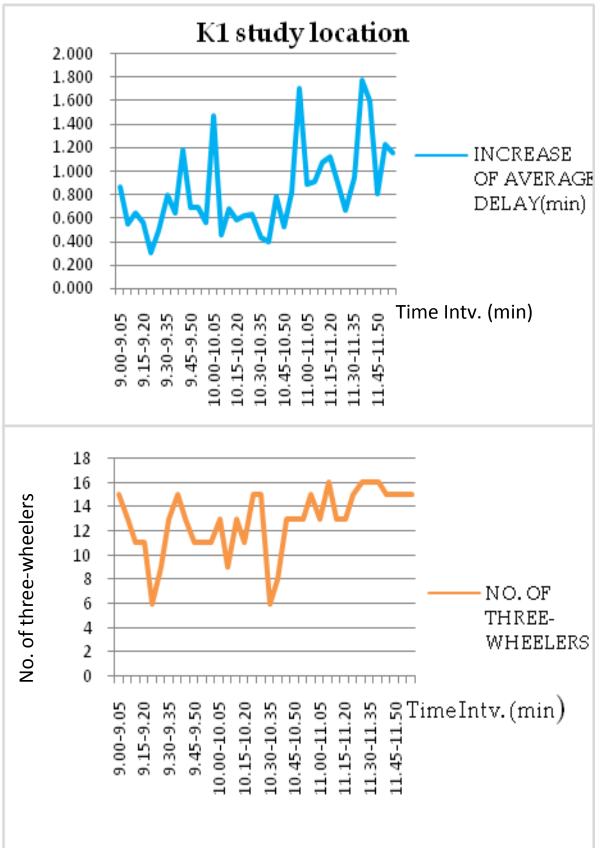
$$Delay = \frac{Total\ Delay}{Number\ of\ Vehicles}$$

$$Delay = \frac{7.06}{11} = 0.6423min$$

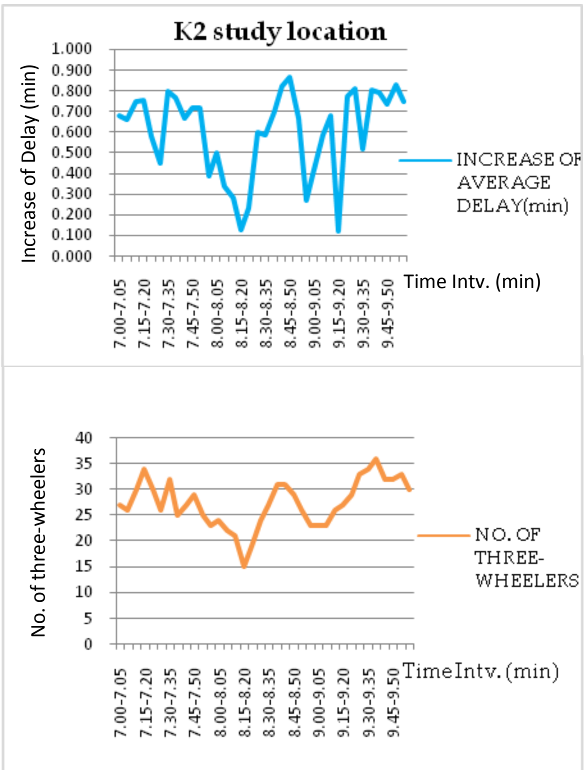
Fig. 6 indicates the effect on the average delays with parked three-wheelers at selected study locations.



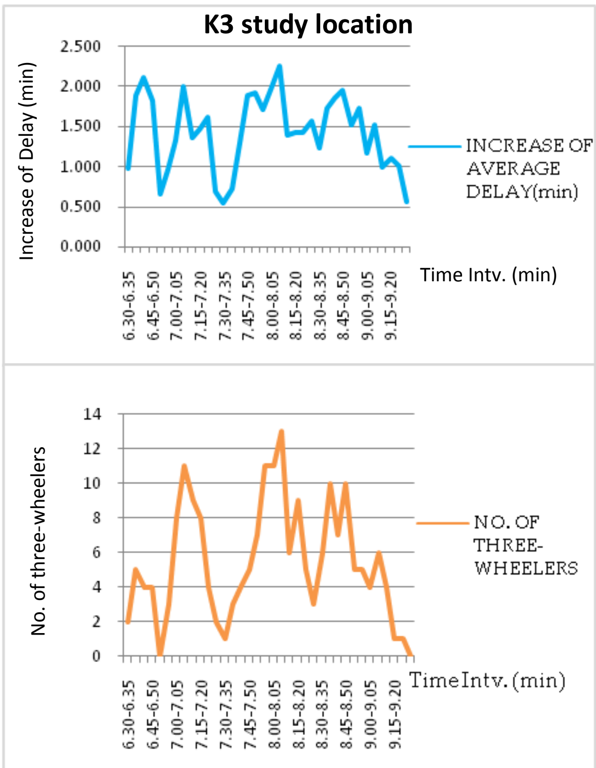
(a) Study Location J1



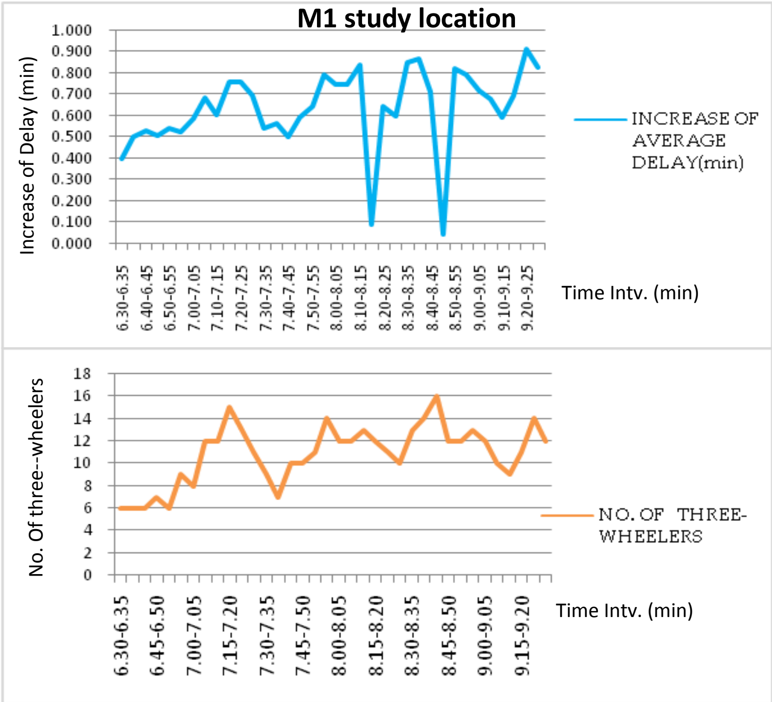
(b) Study Location K1



(c) Study Location K2



(d) Study Location K3



(d) Study Location M1

Fig. 6 Effect on the average delays due to parked three-wheelers

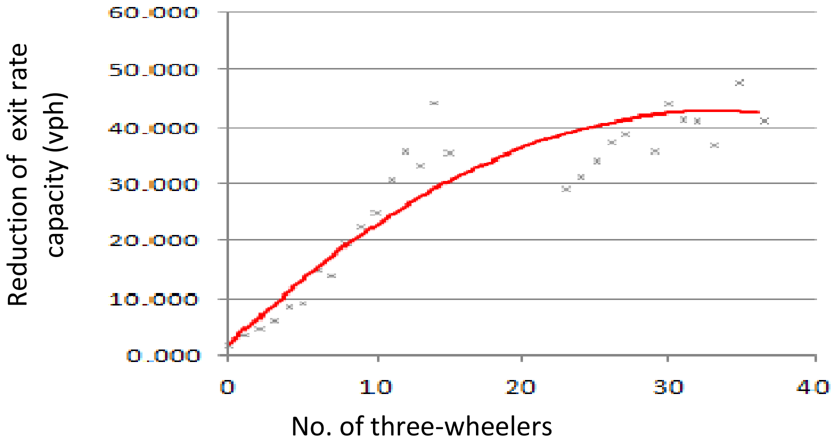
According to the above results there is a considerable increase on average delay (up to 2 minutes at J1, K1 and K3). The increase on average delay was increased when the number of parked three-wheelers increased.

From above observations (Fig.s 5 and 6) following graphs were developed to show the effect for the exit rate and average delay due to the parked of three-wheelers near road intersections.

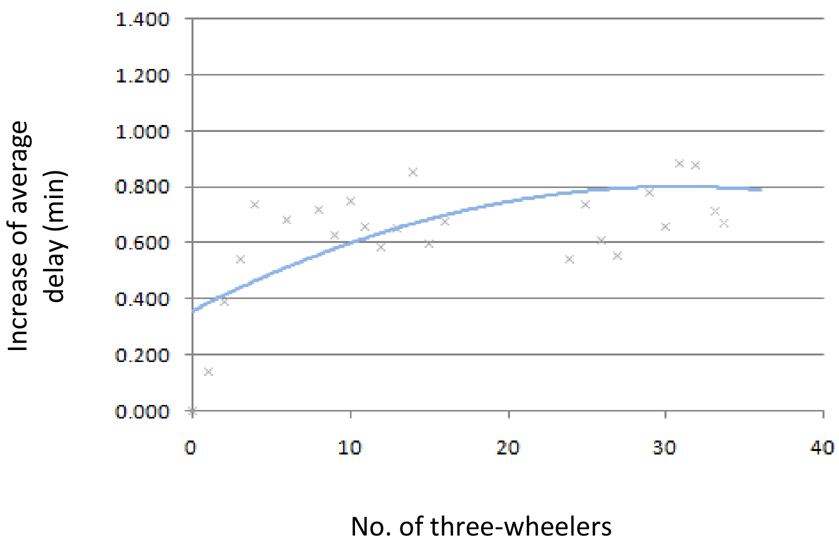
According to the results the number of vehicles which can exit to the major road from the minor road reduced due to the three-wheeler parks near road intersections. The reduction of exit rate was increased, when the number of three-wheelers in the three-wheeler park increased (Fig. 7(a)). According to the Fig. 7(a), reduction of exit rate (up to a maximum of around 45 vph), was increased up to around 30 parked three-wheelers. Then the reduction was stabilized with the increasing number of three-wheelers.

Similarly according to the Fig. 7(b), there was an increase in the average delay of the vehicles entering from minor road to the major road due to the three-wheeler parks near road intersections. The increase of average delay increased (up to about 1 minute) when the number of parked three-wheelers increased.

Increase of average delay was increased up to around 25 parked three-wheelers. Then the increase of average delay was stabilized with the number of three-wheelers increased.



(a) Effect on exit rate of minor road vehicles



(b) Effect on average delay of minor road vehicles

Fig. 7 Effect on exit rate and average delay with number of three-wheelers

6 FINDINGS OF THE STUDY

The results of this study confirm that three-wheeler parks when located near road intersections do have an impact on traffic flow through the intersection. It has an impact on average delay of the vehicles entering from minor road to the major road and exit rate to the major road from vehicles coming from minor road.

The number of vehicles which can enter the major road from the minor road reduced due to the three-wheeler parks near road intersections. The reduction of exit rate increased, when the number of three-wheelers in the three-wheeler park increased. As seen from Fig. 7(a), the exit rate of major road was reduced (almost by 45 vph) up to around 30 parked three-wheelers. Then the reduction was stabilized with the increasing number of three-wheelers.

There was an increase in the average delay of the vehicles entering from minor road to the major road due to the three-wheeler parks near road intersections. The increase of average delay increased when the number of parked three-wheelers increased. According to the Fig. 7(b), increase of average delay was increased (almost by 1 minute) up to around 25 parked three-wheelers. Then the increase of average delay was stabilized with the increasing number of three-wheelers.

From the results of 'before and after' accident statistics too it can be clearly seen that there is a considerable negative effect on the safety of road users near the road intersections due to allowing three-wheelers to be parked near those locations. The average number of accidents was almost doubled near the road intersections after implementing three-wheeler parks (see Appendix A).

7 CONCLUSIONS

It was seen that currently municipal councils and permit issuing institutions do not adhere any proper rules or regulations when permitting three-wheeler parks near road intersections. They permit three-wheeler parks near road intersections mainly based on three-wheeler operators' requests. It was seen that they do not consider a technical analysis on adverse effects caused by the three-wheeler parks to the road users when issuing permission for three-wheelers parks near road intersections.

To eliminate or reduce the negative impacts on the road users, and to improve traffic flows through intersections following suggestions are recommended.

- According to the study results, three-wheeler parks near road intersections cause negative effect for the road users and on the traffic flow. Therefore to eliminate these harmful effects three-wheeler parks near road intersections should not be permitted. In-case where three-wheeler parks are really necessary near intersections, and if sufficient widths of the roads are available, parking area should be at-least 100 meters away from the intersection along the minor road (currently no such distance is specified).

- Municipal councils and permit issuing institutions should develop reasonable guidelines and regulations when issuing permit for locating three-wheeler parks.

- At least for the congested town locations, the permit issuing process should be developed to focus for suitably locating three-wheeler parks.

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APPENDIX – A

Weightages of accidents of study locations

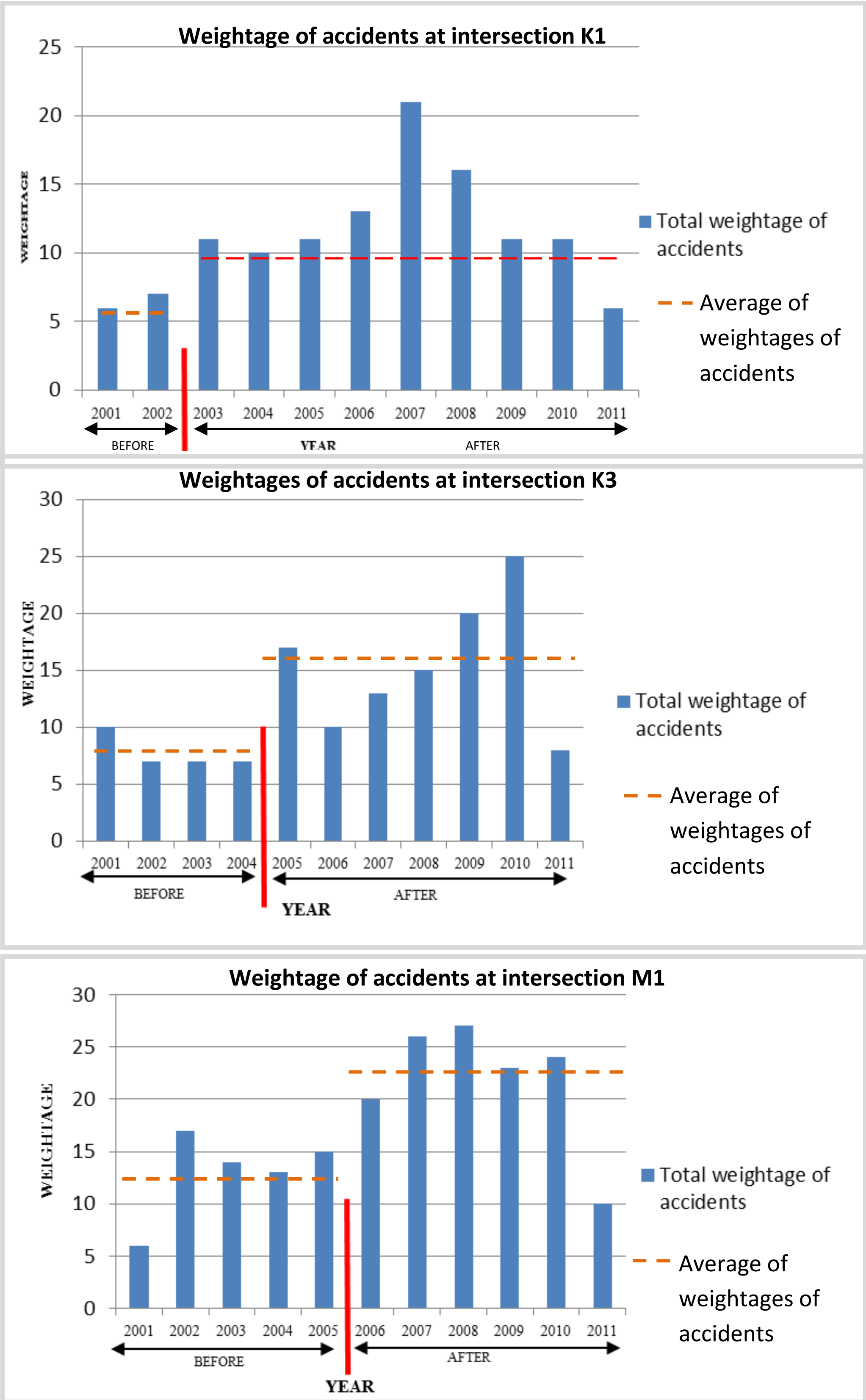

Fig. A1 Accident weightages for locations with three-wheeler parks

Applicability of Use of Fly Ash in Hot Mix Asphalt Concrete

G. H. I. Diyes, K. M. L. A. Udamulla*, and M. N. Tantirimudalige

Department of Civil Engineering, The Open University of Sri Lanka, Nugegoda, Sri Lanka

*Corresponding Author - email: lakshika0807@hotmail.com

Abstract - *Rapid development generates waste and open dumping of waste with related environmental effects has become one of the major problems in Sri Lanka. Fly ash is an industrial waste at the Norochcholai coal power plant. With more power generation by coal, the production of fly ash will increase. Therefore identifying alternative uses of fly ash is very important. Quarry dust which is a byproduct in rock quarries is generally used as the mineral filler in hot mixed asphalt concrete. It is a necessity to safeguard our natural resources by minimizing the excavation of rock formations, sand deposits etc. Therefore, this study investigates the feasibility of using fly ash as a partial substitute to mineral filler in hot mixed asphalt concrete to reduce the consumption of natural resources and minimize environmental hazards that occur through disposal of fly ash.*

Major percentages of pavements in Sri Lanka constructed are asphalt pavements which consist of coarse aggregate, fine aggregate, mineral filler and a bituminous binder. The coarse aggregate is crushed stone with particle size ranging from 2.36mm to 19mm and the fine aggregate is sand or quarry dust, which the size ranges between 0.15mm and 2.36mm. The mineral filler normally used is quarry dust, 85 percent of which passes the 0.075mm sieve. The aggregate mixture is bound together with bitumen. To replace quarry dust with fly ash firstly, the physical properties were examined, to check samples for conformity. Secondly, the Marshall Test method, which is a widely used test recommended by Asphalt institute and presently used by Road Development Authority of Sri Lanka, is adopted for optimizing the proportioning of the asphaltic concrete mix components and the Marshall properties of the samples are checked for conformity. Marshall Test method on three sets of tests were conducted by replacing mineral filler with fly ash in the percentages of 100%, 58% 42% (12%, 7% and 5% respectively from the total weight of aggregates). Results were checked for conformity with specifications of the Institution for Construction Training & Development (ICTAD). ICTAD specifications were fulfilled only for the replacement of 42% of mineral filler with fly ash (5% from total weight of aggregates).

It can be concluded from the results of this investigation that fly ash could be utilized as a partial substitute to mineral filler in hot mixed asphalt concrete. The results of this study will help reduce the consumption of depleting resources such as rock and minimize environmental hazards that occur through disposal of fly ash.

Keywords: *fly ash, mineral filler, hot mix, asphalt concrete*

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1 INTRODUCTION

For the construction of roads two main methods are available. They are concrete paving and asphalt paving. In Sri Lanka the most popular method for all types of roads is asphalt paving method, due to its durability and good finish. Because of the popularity of asphalt paving in Sri Lanka, asphalt has become one of the most important materials for road construction. Aggregates used for asphalt mixtures could be crushed rock, sand and gravel. Aggregates that are used for asphalt paving are mostly extracted from natural resources existing in the country. All these materials are considered as depletion resources. To generate these materials it requires thousands of years.

With the rapid development of the country the generation of waste is also rapidly increased. Under this another new industrial solid waste which is available in Sri Lanka is Fly ash, due to the Norochcholai coal power plant in Puttalam. Approximately about 70000 tons (Source: www.environmentlanka.com/blog/2010) of fly ash generates annually. The people have to face another major problem with disposal of industrial solid wastes. It is therefore pertinent to investigate methods of making use of the solid waste in a profitable manner and mitigate adverse impacts on the environment due to pollution caused by the disposal of fly ash.

Hence it is good to consider how this fly ash can be made use of in the road and highway industry. The study seeks to evaluate the suitability of utilization of fly ash in Hot Mix asphalt and assess the optimum amount of fly ash that can be replaced with quarry dust while retaining the properties of the final product so that the results of this study will help to reduce the consumption of depleting natural resources (rocks) and minimize environmental hazards that occur through disposal of fly ash.

2 GENERAL

Nearly all main highways and road pavements in Sri Lanka are constructed using asphalt mixes which consist of coarse aggregate, fine aggregate, mineral filler and a bituminous binder. The coarse aggregate is crushed stone with particle size ranging from 2.36mm to 19mm and the fine aggregate is sand or quarry dust, in which the size ranges between 0.15mm and 2.36mm. The mineral filler normally used is quarry dust, 85 percent of which passes the 0.075mm sieve.

Asphalt paving has become a popular alternative to concrete due to its durability and flexibility. It can withstand abuse from the weather and punishment from heavy objects. Among the reasons for the popularity of asphalt paving includes elasticity, durability, absorption, decorativeness and affordability. Since it has cooked liquid, it can expand and contract with the weather, making it less prone to frost heaves. Also, it is less likely to crack or lift. Due to its resilience it can withstand heavy weights, such as vehicle traffic. Its dark surface can absorb additional heat in dry weather seasons. Normally asphalt paving has a good finish. It can be stamped like concrete to imitate brick, pavers or cobblestones in any colour and it can form different designs or mosaics. The price of asphalt is less compared to concrete, and it’s quicker to install, reducing labour costs.

An average asphalt pavement consists of the road structure above the formation level which includes unbound and bituminous bound materials. This gives the pavement, the ability to distribute the loads of the traffic before it arrives at the formation level. Normally, pavements are made of different layers. The Fig.1 below depicts the typical layers of a pavement. It is the topmost asphalt layer which is being considered for this research by replacing quarry dust with fly ash.

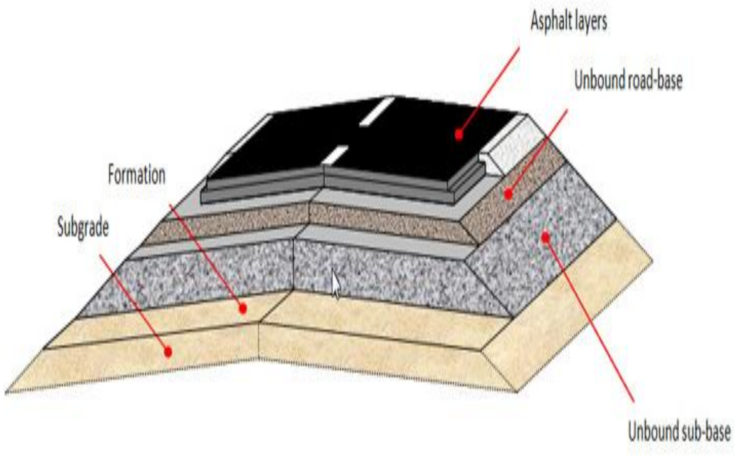

Fig. 1 Different layers of a pavement

To replace quarry dust with fly ash firstly, the physical properties are examined to check samples for conformity. Secondly, the Marshall Test method recommended by the Asphalt Institute of America and presently used by Road Development Authority of Sri Lanka, is adopted for optimizing the proportioning of the asphaltic concrete mix components. The Marshall parameters of the samples are checked for conformity. The parameters evaluated were the compacted density mix (CDM), the percentage of air voids in the mix (VIM), the percentage of voids in the mineral aggregates (VMA), the percentage of voids filled with bitumen (VFB), Marshall Stability and flow. Samples were tested at standard temperature in order to assess the acceptability of the mixes for use in Sri Lanka. The results were compared with standards as per the specifications published by the Institute of Construction Training and Development as shown in Table 1.

Table 1 Marshall Parameters as per ICTAD specifications

Marshall parameter	ICTAD Specification limit
Marshall Stability in kN	Not less than 8
Marshall Flow in (0.25 mm)	8 to 16
Air voids in Mix (%)	3 to 7
Voids in Mineral Aggregates (%)	Not less than 13
Voids Filled with bitumen (%)	70 to 85

3 METHODOLOGY

Following tests were carried out concerning the properties of fly ash to identify how the fly ash could be used in hot mix asphalt concrete.

Sieve analysis was carried out according to Standard Specifications for Hot Mixed and Hot Laid Bituminous Paving mixtures(ASTM D 3515), on a representative sample of the fly ash.

For the determination of specific gravity of fly ash and quarry dust ASTM D 854 was used.

Fineness of fly ash and quarry dust were compared using ASTM C 204. Blaine air permeability test was performed for specific surface test. For Blaine air permeability test a bed of Fly ash and quarry dust was prepared in special permeability cell which have an exact porosity of e = 0.500. The weight of the relevant material is calculated from the following equation,

$$m^1 = 0.500\,\rho\,\rho\,V \qquad [g]$$

Where

P - is the density of the material (g. cm^{-3})

V - volume of the cement bed (cm^3)

Specific surface S is expressed as

$$s = \left(\frac{K}{\rho}\right)\left(\frac{\sqrt{e^2}}{1-e}\right)\frac{\sqrt{t}}{\sqrt{0.1\eta}}$$

Where

K - the apparatus constant

e - porosity of bed

t - the measured time (s)

ρ- Density of cement (gcm^3)

η - the viscosity of air at the test temperature

The results of above tests are given in Tables 2, 3 and 4.

Table 2 Sieve analysis test results for fly ash

Sieve size	Weight retained / (g)	Total weight retained / (g)	% retained	% Passing
2.36 mm	0.64	0.64	0.062	99.938
1.18 mm	4.13	4.77	0.461	99.539
600 μm	10.84	15.61	1.508	98.492
300 μm	25.48	41.09	3.970	96.030
150 μm	414.57	455.66	44.027	55.973
75 μm	363.80	819.46	79.179	20.821
Pan	204.66	1024.12	98.954	1.046

Table 3 Specific gravity of fly ash and quarry dust

Sample No.	Specific gravity	
	Fly ash	Quarry dust
01	2.068	2.429
02	2.044	2.330
03	2.077	2.500
Average	2.063	2.420

Table 4 Specific surface (fineness) of fly ash and quarry dust

Trial	Specific surface	
	Fly ash x *K*	Quarry dust x *K*
01	0.463	0.404
02	0.426	0.416
03	0.474	0.442
Average	0.454	0.421

The mineral filler in asphalt concrete consists of 12% from the total weight of aggregates. Marshall tests were conducted on three trial mixes, by replacing mineral filler with fly ash in the percentages of 100%, 58% 42% (12%, 7% and 5% respectively from the total weight of aggregates). Due to time constraints and each replacement needs 36 tests, only these three replacements were considered. The mineral filler was added to 57.5% and 30.5% of coarse and fine aggregates, respectively (Asphalt Institute, 1997). These aggregate proportions are typical of wearing course mixes normally used for main roads in Sri Lanka. Standard Marshall Specimens (63.5 mm height and 101.6 mm diameter) were prepared in the following manner. Weight of bitumen was varied from 3.5% to 6% in steps of 0.5%, resulting in six percentages by weight of bitumen content, and three samples were prepared for each bitumen percentage. The grading and proportions were kept constant for all the mixes by sieving the aggregates to individual sizes and then recombining them in a continuous grading required by the local standards.

The same quantity of materials was used for each sample in an effort to obtain approximately the same height of the specimens. The mix was first partially compacted using a heated standard rod, fifteen times around the perimeter and five times in the center. The whole mould was then fixed in the Marshall Compaction machine which consists of a 4.5 kg hammer falling from a distance of 457 mm. Both sides of the samples were compacted 75 times. The compacted samples were allowed to cure overnight at room temperature. The density of the samples was then determined by obtaining the submerged weight in water and weighing the samples in air.

Samples were then tested at standard temperature (60^{0}C) in the Marshall machine and the deformation stability (in kN) and the flow of the samples (in mm) were recorded. The Marshall parameters of the samples were also checked for conformity.

The same procedure was repeated for all samples.

4 TEST RESULTS OF MARSHALL TEST

4.1 Replacing 100% of mineral filler with fly ash

The average Marshall Stability and flow values for replacing 100% of mineral filler by fly ash are given in Table 5.

Table 5 Average Marshall Stability and flow values for replacing 100% of mineral filler by fly ash

% of bitumen by weight	Marshall stability (kN)	Flow (mm)
3.5	5.37	5.07
4	7.15	6.15
4.5	7.03	5.88
5	9.02	5.57
5.5	10.39	6.36
6	8.29	6.18

4.2 Replacing 58% of mineral filler with fly ash

The average Marshall Stability and flow values are given in Table 6 for replacing 100% of mineral filler by fly ash.

Table 6 Average Marshall Stability and flow values for replacing 58% of mineral filler by fly ash

% of bitumen by weight	Marshall Stability (kN)	Marshall flow (mm)
3.5	2.02	6.37
4	5.43	5.81
4.5	6.21	6.34
5	8.08	8.79
5.5	1.05	12.02
6	-	7.957

4.3 Replacing 42% of mineral filler with fly ash

Table 7 indicates the average Marshall Stability and flow values for replacing 42% of mineral filler by fly ash.

Table 7 Average Marshall Stability and flow values for replacing 42% of mineral filler by fly ash

% of bitumen by weight	Marshall Stability (kN)	Marshall flow (mm)
3.5	7.509	4.531
4	8.328	4.876
4.5	9.143	4.230
5	7.968	4.209
5.5	8.594	3.627
6	10.230	5.007

According to the test results of Table 5 and 6 it can be seen that the two most important parameters namely Marshal stability and Marshal flow do not conform with the ICTAD specifications. However, the results of Table 7 indicate that both the Marshal Stability and flow values are in agreement with the ICTAD specifications for the bitumen content of 5.5%. Therefore, the rest of the Marshall parameters for the 42% of replacement of the mineral filler with the fly ash were determined for conformity and the results are given in Table 8. Fig. 2 indicates the acceptability of the specimen by replacing 42% of mineral filler with fly ash.

Table 8 Average Marshall Test results for replacing 42% of mineral filler by fly ash

% of bitumen by weight	Average CDM (g/cc)	Average VIM (%)	Average VMA (%)	Average VFB (%)
3.5	2.290	5.340	13.198	61.9
4	2.245	6.546	15.350	58.2
4.5	2.340	1.904	12.227	84.8
5	2.301	2.862	14.142	81.3
5.5	2.248	4.439	16.561	73.4
6	2.272	2.752	16.116	83.0

Fig. 2 represents the acceptability of the specimen by replacing 42% of mineral filler with fly ash

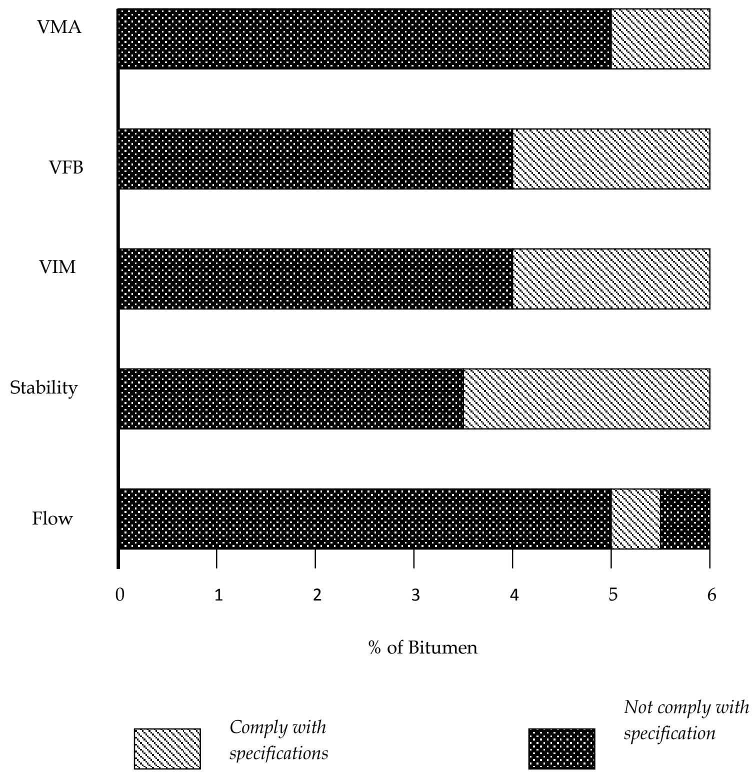

Fig. 2 Acceptability of the specimen by replacing 42% of mineral filler with fly ash

Finally the test results were compared with the ICTAD specifications and the final comparison is given in Table 9.

Table 9 Marshall Properties of asphaltic mix at bitumen content of 5.5% compared with ICTAD specifications

Marshall parameter	Value at 5.5% bitumen content	ICTAD Specification limit
Marshall Stability in kN	8.6	Not less than 8
Marshall Flow in (0.25 mm)	14.51	8 to 16
Air voids in Mix (%)	4.44	3 to 7
Voids in Mineral Aggregates (%)	16.56	Not less than 13
Voids Filled with bitumen (%)	73.4	70 to 85

5 CONCLUSIONS

From the results, the following can be concluded:

- According to the sieve analysis test results, it is proved that the fly ash from Norochcholai coal power plant meets the ASTM requirements for mineral filler.
- Fly ash from Norochcholai coal power plant has a specific gravity of 2.063, closer to that of quarry dust which has the specific gravity of 2.420. So it is considered that it could be used as the mineral filler in Hot Mix Asphalt, because most conventional mineral fillers have a specific gravity in the 2.6 to 2.8 range.
- Fineness of the fly ash when compared with the quarry dust was found to have a slightly higher value. Theoretically higher fineness may indicate more effective mineral filler, although the higher fineness also means a greater surface area of particles that must be coated, resulting in an increase in asphalt content of the mix.
- Results conforming to specifications were obtained only for replacement of 5% of mineral filler from the total weight of aggregates with fly ash (42% of mineral filler)
- The stability value of replacing 5% of mineral filler from total weight of aggregates with fly ash was well above the minimum (8 kN) criteria in ICTAD specification.
- For this replacement of 5% of mineral filler from total weight of aggregates with fly ash, the optimum bitumen content by weight of the aggregates was 5.5% which satisfied the ICTAD specifications.

Hence it can be concluded that, fly ash can be utilized as a partial replacement for the mineral filler in hot mix asphalt concrete wearing courses used in Sri Lanka.

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Impact of Selected Finishing Treatments on Strength Properties of Trouser Materials

G. B. Delkumburewatte* and Amila Madusanka

Department of Textile and Apparel Technology, The Open University of Sri Lanka, Nugegoda, Sri Lanaka

*Corresponding Author - email: gbdel@ou.ac,lk, Tel: +94112881307

Abstract - *Washing and finishing treatments for trouser materials are required for the purpose of improving comfort and visual appearance to match occasion. Simultaneously consumers expect an improvement of performance characteristics and durability of garments or at least to remain as it was before the treatment. According to the previous research work and experience of the industrialists washing and finishing treatments affect physical properties of the woven garments.*

In this study, the effect of different washing treatments such as enzyme, stone, bleaching, permanganate spray and normal garment washing on the denim, corduroy, drill and twill fabric materials was investigated. Tearing strength and breaking strength of the fabric before and after each treatment were measured and compared. The results show that all such treatments carried out with the objective of obtaining worn appearance and aged look of the garments have resulted in reduction of the breaking and tearing strengths. Further, it has revealed that all the investigated washing and finishing treatments except the normal garment washing resulted in higher levels of reduction of warp yarn strength than that of the weft yarn strength.

It was evident that the bleaching and stone washing treatments were the most aggressive affecting the strength properties of the fabrics to the highest levels. Longer the duration of the treatment, the higher is the decrease of both tearing and breaking strengths.

It is advisable to follow washing or finishing procedures without bleaching treatment. To ensure a lesser effect on the performance characteristics of the garments, the treatment conditions have to be optimized.

Key words: *Washing and Finishing treatments, Trouser material, Breaking Strength, Tearing strength.*

Nomenclature

BS – Breaking strength under tensile force in kilogram force (Kgf)
TS – Tearing strength in gram force (gf)
GW – Normal garment wash
GSM – Area density in grams per square meter
ori – strength values of untreated (original) fabric

1 INTRODUCTION

In the garment industry, different washing and finishing treatments are carried out very often on complete garments in order to obtain various finishing effects, improving comfort etc. Washed/finished garments have become a fashion and at present of very high demand. Most of these washing and finishing treatments are done in aqueous medium with chemicals; for example enzyme washing, stone washing, bleaching, permanganate spray, normal garment washing [Anthony P *et al*., (2001), Militky J *et al*., (1997), Pederson L. *et al*., (1994)]. Some other treatments are physical treatments such as brushing, sanding etc, which are dry process involving only physical changes in the garments. It is reported that washing and finishing treatments do not only improve the aesthetics and comfort properties as demanded by the consumer but also significantly affect the fabric mechanical properties negatively [Faouzi K. *et al*., (2009), Ayanna C *et al.* (2006)]. The most important mechanical property which affects the performance as well as durability characteristics of a garment is the strength of the fabric out of which the garment is made. In the case of woven fabrics, both tensile strength and tearing strength are considered in the evaluation of fabric strength. According to the Danija and Manisha, (2007) tearing strength, which is usually measured as the force required to propagate a tear, may often be used to give a reasonably direct assessment of serviceability. A fabric with low tearing strength is considered generally as an inferior product.

Faouzi K. et al., (2009) reported that bleach-treatment on denim fabrics reduces the breaking strength (BS) by 12% and tearing strength by (TS) by 29% in warp direction. TS of denim fabrics subjected to bleaching depend on the duration of the treatment. It is reported that treating of fabrics over 10 and 30 minute durations resulted in a warp way reduction of tensile strength in 8% and 35% while weft way reductions were 2% and 11% respectively. After subjecting the same fabrics to sanding with potassium permanganate treatment, TS was decreased by 2% in warp direction and 1.3% in weft direction.

However, the normal garment washing treatment has increased the Tensile Strength by 12% in warp direction and by 9% in weft direction in Denim fabrics [Faouzi K. et al., (2009)].

It appears that the warp yarns are weakened more than the weft yarns by different treatments. In the case of 3/1 twill fabrics, the abrasion is concentrated more on warp yarns than on weft yarns. When fabrics are subjected to stone and enzyme wash, the surface fibres of the fabric are aggressively damaged and removed causing more degradation and decreasing of mechanical properties (Faouzi K. et al., 2009).

The fibres are damaged more by enzyme washing than by stone washing due to hydrolysis of cellulose molecules [Weltrowski, (1995) and Pederse, (1993)]. Charles T (1992) stated that bleaching of cotton fabrics with oxidizing agents cause degradation of cellulose molecules in the fibre. His suggestion was to optimize bleaching conditions to optimize whiteness while minimizing fiber damage (Charles T, 1992).

Broad objective of this study was to determine the effect of finishing treatments on the strength properties of different trouser materials and to make recommendations for optimizing treatment condition to minimize strength reduction.

The trouser materials used for this research have similar structures to those used by previous researchers, but different in area density. Some of the treatment conditions such as treatment duration and concentration of the chemical baths were different. But the treatment sequences were same as in previous research.

1.1 Objectives

The broad objective of the study was to investigate the influence of some selected finishing treatments on the strength properties of trouser materials used in Sri Lankan garment industry. Followings are the specific objectives of this study:

- To study the influence of enzyme treatment and normal garment wash treatments on breaking strength (BS) and tearing strength (TS) of corduroy and twill trouser materials
- To study the influence of enzyme wash, stone wash with enzyme and normal garment wash treatments on breaking strength (BS) and tearing strength (TS) of drill trouser material
- To study the influence enzyme wash, stone wash with enzyme, bleaching, sanding with permanganate spray and normal garment washing treatment on breaking strength (BS) and tearing strength (TS) of denim trouser material.

A preliminary survey done on the testing reports from testing laboratories in Sri Lanka revealed that physical property failures are higher than other defects after subjecting the trouser materials to various finishing treatments. Among those physical properties, strength reduction in breaking strength and tearing strength are at the first place. Thus, selected fabrics denim, twill, drill, corduroy and the selected finishing treatments are currently heavily used by the Sri Lankan garment industry to give various finishing effects.

2 METHODOLOGY

2.1 Materials

Table 1 shows the selected fabric types, their composition, woven structure and area density (GSM). The selected fabrics differ by their area density, material composition; weave type, and warp and weft densities.

Table 1 Specifications of the selected fabric samples

Fabric type	notation	Composition and weave (warp and weft density/inch)	Area density (g/m^2)
Denim	F1	100% Cotton, weave 3/1(88x60)	265
Drill	F2	98% Cotton,2% Elastane, weave 3/1(80x41)	373
Corduroy -Blue (CB)	F3	98%Cotton, 2%Elastane, weft cut pile (136x42)	290
Corduroy –White (CW)	F4	99% cotton, 1%Elastane, weft cut pile (96x60)	345
Twill (White)	F5	99% Cotton, 1%Elastane, weave 2/1 (105x48)	227
Twill (Blue)	F6	100% Cotton, weave 2/1 (126x56)	202
Twill (Red)	F7	52% Cotton , 48% Polyester, weave 2/1 (124x59)	216

2.2 Treatment procedures

Samples were prepared as trouser legs, which had 17'' length and 8'' tubular width. There were a total of 111 leg-shaped samples prepared for this study (three leg shaped samples for each finishing treatment). Table 2 shows the finishing treatments, treatment conditions and the duration applied for different fabric types.

Table 2 Treatment variables

Treatment	Condition	Time
Enzyme wash (T1)	Temperature=55°C Enzyme: Acid Enzyme(pH-5) for Denim Neutral Enzyme for Twill, Corduroy	30 min., 60 min. and 90 min.
Stone + enzyme wash (T2)	Temperature:55°C Stone: New stones and worn out stone 1Kg of sample/ 2Kg stone	30 min., 60 min., and 90 min.
Sanding (T3) Permanganate spray	Rotation peed: 120 rpm (round/min.) Pressure:2.5 bars Distance of pulverization:40-50 cm Spray capacity 50 to 65 ml for a surface of 0.2 m^2	20 min. Depend on design
Bleaching (T4)	Product: 75.ml/l of water of (70% chlorinate) +stone	Depending on fabric type 10min. & 30min.
Normal garment washing and rinsing (T5)	Eco softener (10-10), 1/10 in water in room temperature)	10 min.

All different fabrics given in the table 1 were not treated by all the finishing treatments described in the Table 2. The finishing treatments applied to different fabrics depend on the type of fabric and the final properties and characteristics expected from them. Hence each fabric type was treated only by those treatments which are usually applied to that particular fabric by the industry. The table 3 gives the treatments applied for different fabrics (F1 – F7).

Table 3 The treatments applied to different fabrics

	F1	F2	F3	F4	F5	F6	F7
Enzyme wash, T1	√	√	√	√	√	√	√
Stone enzyme wash, T2	√	√					
Sanding, Permanganate spray, T3	√						
Bleaching, T4	√						
Normal Washing, T5	√	√	√	√	√	√	√

TS and BS of untreated and treated fabric samples were measured in warp and weft directions. There were 84 test results obtained from the fabric samples before treatment (7X2X2X3 = 84) and 444 specimens were used to measure the strength of treated fabrics (111 samples x 2 –warp & weft directions- x 2 –TS and BS-= 444). Therefore, 528 (84+444) fabric specimens were prepared for the whole series of strength testing. Specimens were properly dried and conditioned under standard atmospheric conditions after the treatments prior to testing. T. S. and BS were measured according to the standards ASTM D1424 and ASTM D5034 respectively.

3 RESULTS AND DISCUSSION

3.1 Effect of enzyme and normal garment wash treatments on Tearing Strength and Tensile Breaking Strength of Corduroy Fabrics (F3 and F4)

Fig. 1 shows how TS in warp and weft directions of corduroy blue and white fabrics is affected by enzyme (T1) and Normal wash treatments (T7), GW. Corduroy blue (CB) shows higher TS in warp direction than that in weft direction before the treatments. But in the case of corduroy white it shows opposite behavior.

In all the fabrics, TS is generally increased by 10 minute normal washing treatments in both warp and weft directions.

Same tendency can be observed in both fabrics after the application of 30 minute enzyme wash treatment.

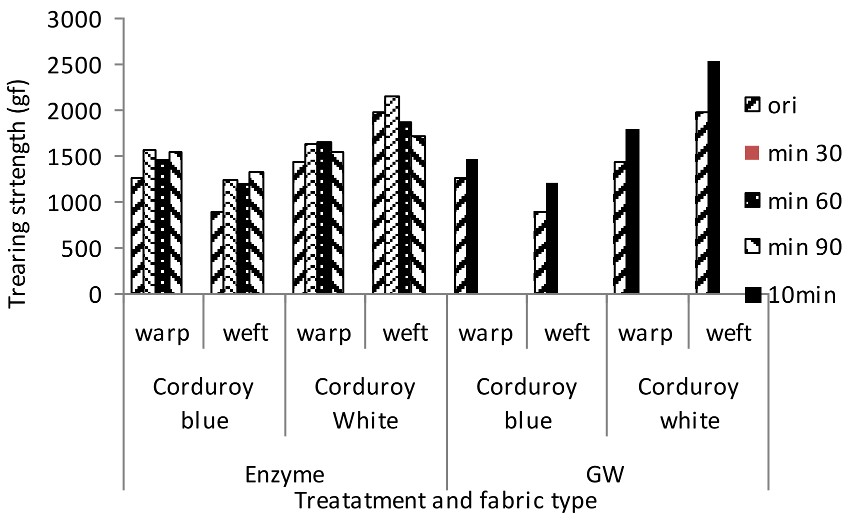

Fig. 1 Effect of enzyme and normal garment wash (GW) treatments on tearing strength of corduroy white and blue fabrics

After the 30 minute- enzyme wash treatment, TS of CB fabrics have increased in 24% and 36% in warp and weft directions respectively. After the 60 minute- enzyme washing TS in warp and weft directions of CB fabric has decreased in 8% and 4% respectively, compared to the values after 30 –minute treatment. However the 90 minute- enzyme wash treatment has reduced the TS of CB fabrics only in the almost same amounts as in the case of 30 minute treatment. The increases of TS in warp and weft directions of the CB fabric after GW treatment are 16.7% and 32.1 % respectively. In contrast to CB fabric, corduroy white (CW) fabric shows higher TS values in warp direction in comparison to the TS in weft direction. Both 30-minute enzyme wash and 10 minute GW treatments increase the TS in both warp and weft directions. After 30 minute-enzyme wash treatment, TS of CW fabric shows the increases of 12.65% and 9.39% in warp and weft directions respectively. However, 60 minute enzyme wash treatment does not change the TS in warp direction in comparison to 30 minute treatment, but, 5.23% drop in TS is indicated in weft direction. Increase of enzyme treatment duration to 90 min. results in further decreases of TS in 6.6% and 21.8% in warp and weft directions respectively in comparison to the TS values after 30-minute treatment.

The 10-minute normal wash treatment of CW fabric causes the increases of TS in 23.38% and 27.7% respectively in warp and weft directions compared to the TS values of the untreated fabrics.

Accordingly, enzyme treatment of 30 min. gives the maximum increase of the TS in both weft and warp directions of both blue corduroy and white corduroy fabrics.

Fig. 2 shows how BS in warp and weft directions of coduroy blue and white fabrics is affected by enzyme (T1) and Normal wash treatments (T7),

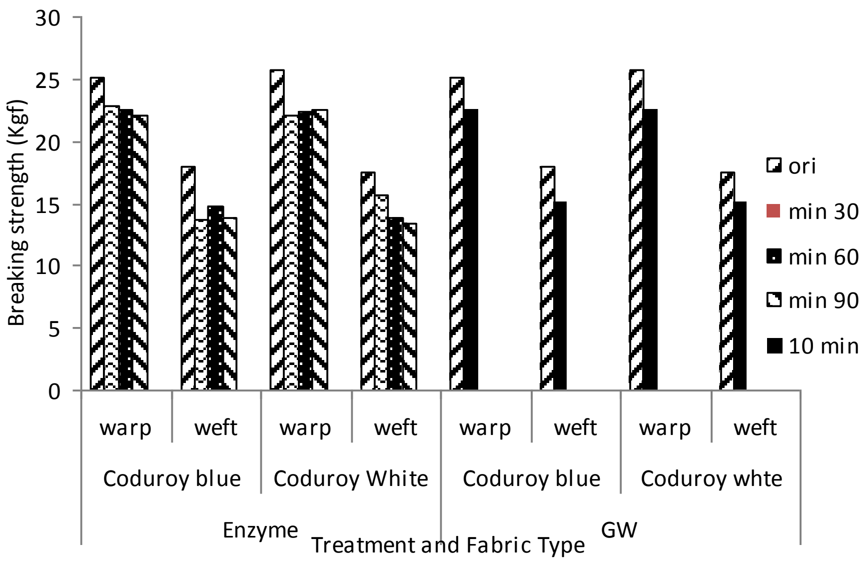

Fig. 2 Effect of enzyme and normal wash treatments on breaking strength of corduroy white and blue fabrics

According to the Fig. 2, breaking strengths under tensile load in both warp and weft directions of both types of fabrics after enzyme treatment have decreased in comparison to strength of the untreated fabrics. These reductions amount to 9-15% in warp direction and 10-24% in weft direction. Reason for the reduction can be the damage to the cellulose molecules in the Cotton fibre**.** However the variation of the duration of the enzyme treatment from 30 minute to 90 minute has no significant effect on the BS of both CB and CW fabrics except on the weft way strength of CW fabric.

It can be observed a reduction of BS in weft direction of CW fabric with the increase the duration of the enzyme treatment from 30 minutes to 60 minutes and then to 90 min.

Normal washing treatment of 10 minutes duration brings about an almost similar reduction of BS in both warp 9.59% -12.23% and weft 13.88% -15.34% directions for both CW and CB fabrics. This may be due to the lesser ground weft densities than the ground warp densities in corduroy fabrics.

3.2 Effect of enzyme and normal garment wash treatments on tearing strength and breaking strength of twill Fabrics (F5, F6 and)

Fig. 3 shows how TS in warp and weft directions of Twill white, Twill blue and Twill red fabrics is affected by enzyme (T1) and normal wash treatments (T7), GW. According to the Fig. 3 and the table given in Appendix 6**,** TS of twill fabric samples have increased in both warp and weft directions after both the treatments (T1 and T7) in comparison to TS of untreated original fabrics.

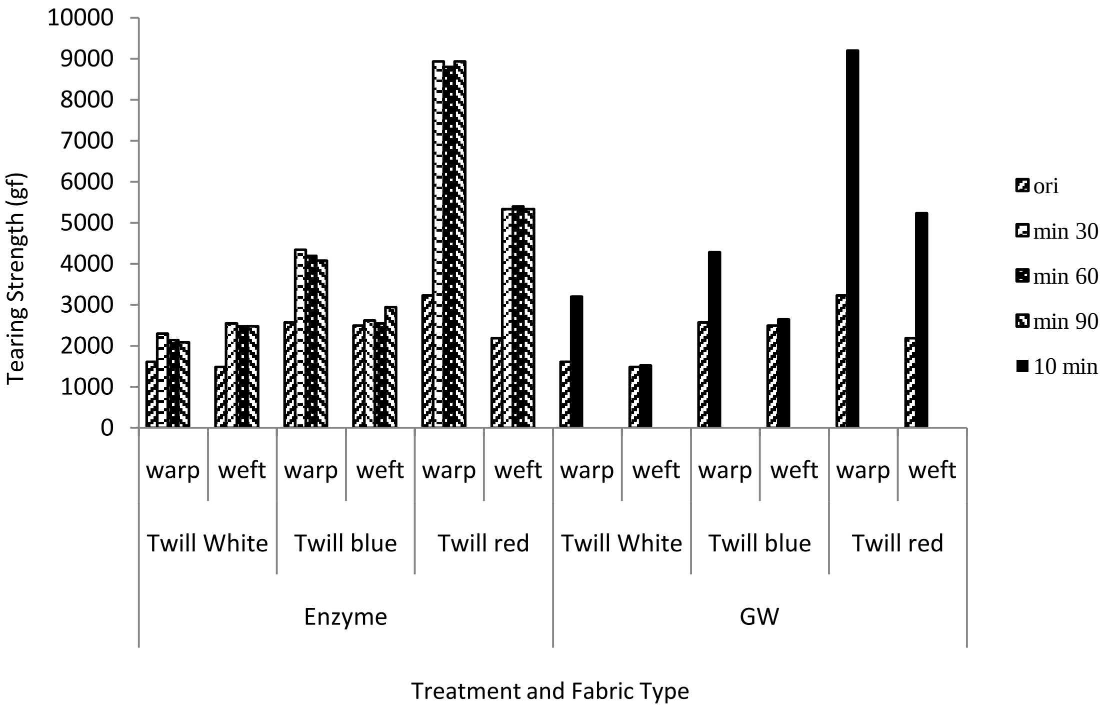

Fig. 3 Effect of enzyme and normal wash treatments on tearing strength of twill fabrics

It can be observed that the TS in warp and weft directions of all three twill fabrics have slightly decreased with increasing of the duration of enzyme wash treatment from 30 min. to 60 min. and then to 90 min., where as in the TS values in weft direction do not show such a trend. The TS of red colour twill fabric has exhibited an increase of more than 100% in both warp and weft directions compared to the TS of untreated fabric. This behavior must be analyzed in depth in relation to the fabric construction details.

Fig. 4 shows the effect of enzyme and normal (GW) wash treatments on BS in both in warp and weft directions of twill fabrics. BS under tensile loading in warp direction is higher than that in the weft direction for all three types of fabrics. When comparing three fabrics, BS in warp direction of the red twill fabric is much higher than the BS values in warp direction of the other two fabrics. Hence, red twill fabric shows higher BS in warp direction even after the two different treatments.

In contrary to the behavior of TS, BS in warp and weft directions of all twill fabrics have decreased after the two types of treatments. The decrease range gave 13-24% in warp direction and 23-40% in weft directions of twill fabric samples.

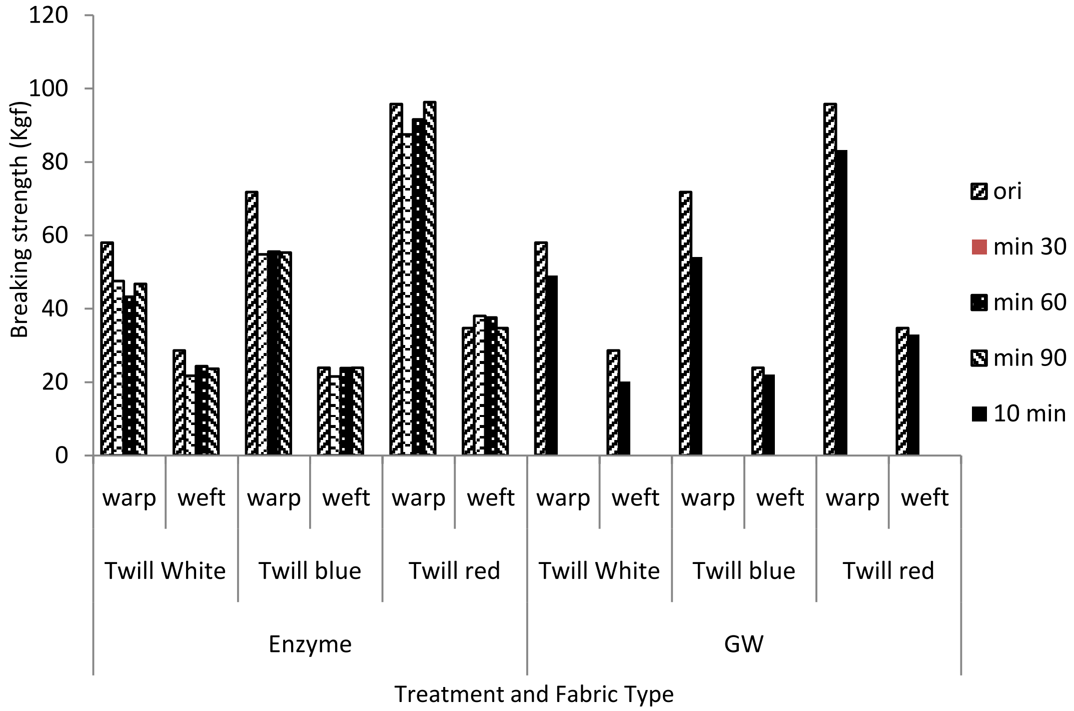

Fig. 4 Effect of enzyme and normal garment wash treatments on breaking strength of twill fabrics

It appears that enzyme treatment even at 90 minute duration does not affect the strength properties of the fabrics significantly. Even the normal washing treatment can have effects of similar magnitude. Hence we can conclude that the enzyme treatment under above conditions can be used without any hesitation to achieve the required comfort or aesthetic style features.

3.3 Effect of enzyme wash, stone enzyme wash and normal garment wash on tearing strength of drill Fabrics (F2 fabric)

Fig. 5 shows the effect of enzyme wash (T1), stone enzyme wash (T2) and normal garment wash (T6, GW) on the TS of drill fabrics.

The TS in weft direction is lower than that in warp direction before and even after all three different treatments. Due to enzyme treatment, TS in warp direction of the drill fabric (F2) has increased by 12%- 14.5% but the TS in weft direction has decreased by 10.5% -13.5%.

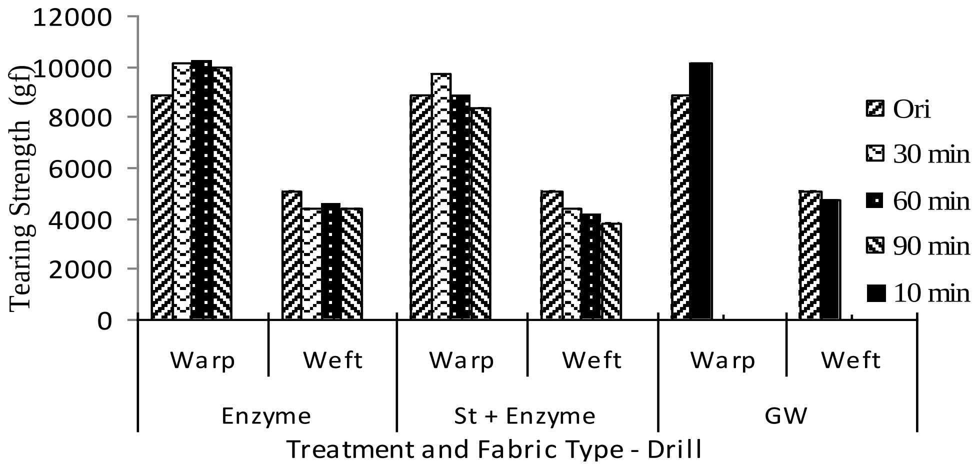

Fig. 5 Effect of enzymes, stone enzyme wash and normal wash on tearing strength of drill fabrics

The change of duration of the enzyme wash treatment from 30 minutes to 90 minutes does not cause any significant differences.

Enzyme stone wash treatment carried out under different durations brings about differences in tearing strength in both warp and weft directions. 30 minute enzyme stone wash treatment has increased the TS in warp direction of drill fabric by 9.5%-, but increasing of the duration to 60 and 90 minutes has decreased the TS in warp direction by 0.56% and 5.6% respectively in comparison to the tearing strength of untreated fabric. It is also observed that the TS in weft direction of the drill fabric has decreased by 12.6%, 18.4 % and 25.5% after 30 min., 60 min. and 90 min. durations of the enzyme stone wash treatment.

Normal (GW) wash treatment increases the TS in warp direction of the drill fabric but decreases the TS in weft direction. Fig. 6 illustrates the effects of enzyme wash, stone enzyme wash and normal garment wash (GW) t on the BS under tensional loads of the drill fabric.

Fig. 6 shows that the drill fabric has a higher breaking strength in warp direction than that of weft direction irrespective of the treatment condition. Thus, BS in warp direction of the drill fabric has slightly increased by 3.1% due to 30 minute application of enzyme wash treatment. However, 60 and 90 minute enzyme treatments have slightly reduced the BS in warp direction compared to the strength of the fabric treated 30 minutes duration. Effect of the duration of enzyme treatment varying from 30 to 60 and then to 90 min. on weft way BS is insignificant.

Application of enzyme stone wash treatment to the drill fabric also has a very small effect on the BS on both warp and weft direction. The BS has decreased in 5.6% - 6.3% (in average) compared to the value of untreated fabric.

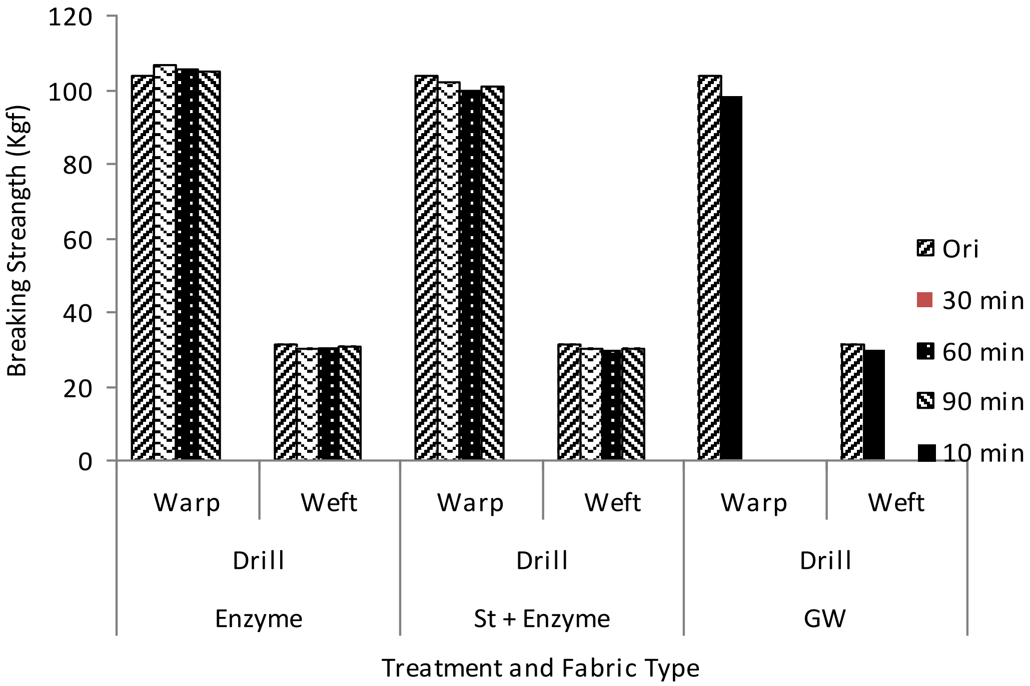

Fig. 6 Effect of enzyme, stone enzyme and normal wash treatments on breaking strength of drill fabric

Breaking strength of drill fabric decreases in both weft and warp directions in all treatments other than 30 minute of enzyme treatment. This may be due to breaking of cellulose molecules in cotton fibre structure, after reacting with the enzyme.

Depending on the required aesthetic and comfort characteristics, any of the above treatments can be employed as their effect on BS and TS are insignificant.

3.4 Effect of enzyme wash, stone enzyme wash, sanding with permanganate spray, bleaching and normal garment wash treatments on tearing strength and breaking strength of denim fabrics (F1 fabric s)

Fig. 7 shows the effect of enzyme wash, stone enzyme wash, bleaching, sanding with permanganate spray (SB+PS) and normal garment wash (GW) on TS of denim fabrics.

According to the Fig. 7, TS in warp direction of denim fabrics has decreased by 29% - 30.5% after subjecting to enzyme wash, enzyme stone wash, bleaching and (SB + PS) treatments compared to the TS of untreated fabric. The TS in weft direction of the denim fabric has increased by 5.5% - 7% due to the application of enzyme wash and enzyme stone wash treatment. Bleaching carried out over 10 minute duration has resulted in slightly lower TS reduction of about 4.99%**.** Bleaching of denim for 30 minutes has decreased the tearing strength in warp direction by 46.8% and but only 3.0% in weft direction. Application of (SB + PS) treatment on denim fabric has reduced TS in weft direction by 5.9 to 10.6% of the TS of untreated fabric.

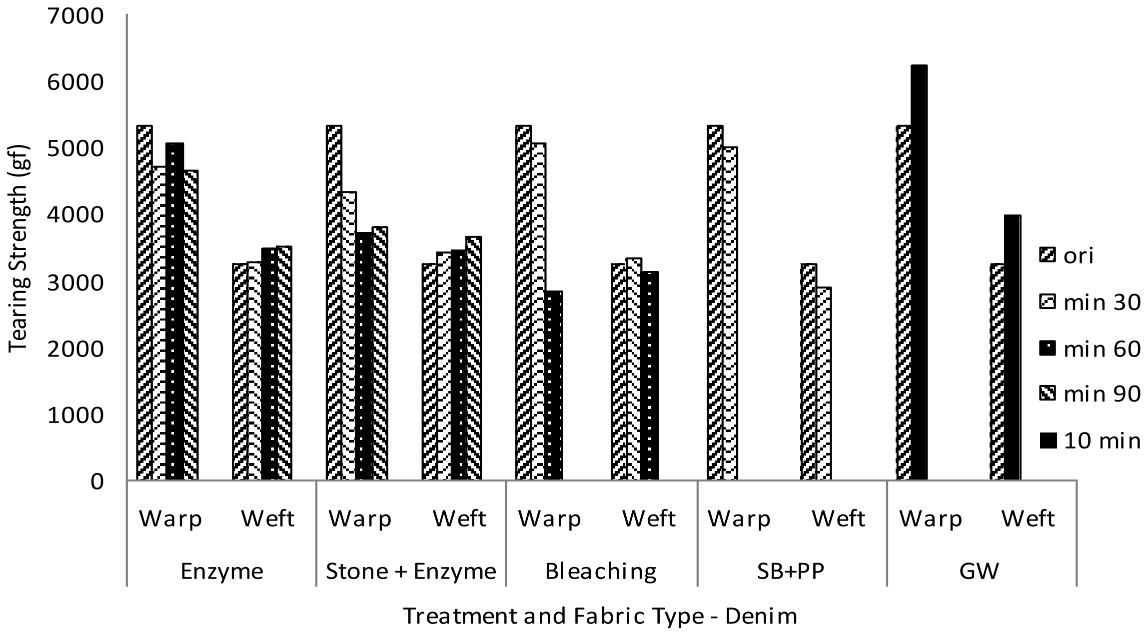

Fig. 7 Effects of enzyme wash, stone enzyme (stone + enzyme), bleaching, sanding with permanganate spray (SB+PS) and normal garment wash treatments on tearing strength of denim fabrics

Further, Fig. 7 shows that the TS in both, warp and weft directions have reduced in about 5% due to 30minute (SB + PS) treatment. TS in warp and weft directions of denim have increased by 16.88% and 23.16% respectively of untreated fabric due to normal wash treatment.

Fig. 8 shows the effect of enzyme wash, stone enzyme wash, bleaching and sanding with permanganate spray (SB+PS) as well as normal wash (GW) treatments on BS of denim fabrics. It is evident that the BS in both weft and warp directions of denim fabric decreases in general after enzyme, stone enzyme, bleaching, sanding with permanganate spray and normal garment wash treatments. BS in warp direction of the denim fabric has shown a significant reduction due to 90 minute enzyme wash treatment in comparison to 30 minutes and 60 minutes duration treatments. However, it was not observed any effect of the duration of the enzyme treatment on the weft way strength of the denim fabric. As shown in the Fig. 8, BS in warp and weft directions of the denim fabric has decreased by 28% - 31% and by 5.5% - 6.5% respectively after subjecting to enzyme stone wash treatment. Reason may be that the warp yarns of the denim fabric with 3/1 weave are more intensively rubbed by stones during the treatment than the weft yarns as this is a warp fabric. However the time duration of the application of enzyme stone wash treatment has no effect on the strength in warp direction as rubbing of surface yarn (warp) has taken place during the first 30 minutes of treatment Thus, there can be no significant differences observed in weft direction samples compared to the values of untreated fabric. In addition, variations of BS in weft direction due to change of the duration of application of enzyme stone wash treatment are also insignificant.

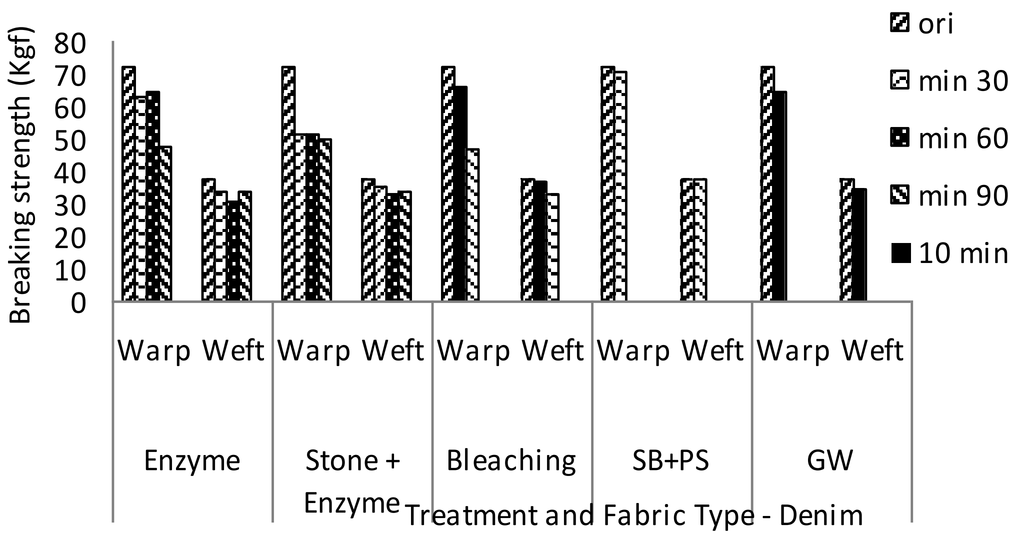

Fig.8 Effect of applying enzyme wash, stone enzyme (stone + enzyme), bleaching, sanding with permanganate spray (SB+PS) and normal garment wash treatment on the breaking strength of denim fabric

As shown in the Fig. 8, BS in warp direction of denim fabric is significantly affected by increased time of application of bleaching treatment. But, it appears that the weft way strength of the denim is affected to a lesser extent. According to Faouzi K. *et al.,* (2009), bleaching treatment weakens the BS in warp direction of denim by 12%.

Due to sanding and potassium permanganate spray treatment BS was decreased by 2% in warp direction and 1.3% in weft direction compared to the BS of untreated fabric. However normal garnet washing has a higher effect, because BS in warp and weft directions of denim has decreased by 12% and 9% respectively due to normal garment washing.

4 CONCLUSIONS

Finishing treatments of garments/fabrics are aimed at improving, visual and comfort characteristics. However, such treatments affect also the fabric performance characteristics such as tearing strength and breaking strength negatively or positively. This paper deals with the influence of some selected finishing treatments on tensile and tearing strength of some selected woven fabrics. The investigated finishing treatments affect both the breaking strength in warp and weft direction negatively. However, the normal garment washing treatment affects breaking strength in warp and weft direction positively. In general finishing treatments affect tearing strength in both warp and weft directions positively. The positive effect on tearing strength of treated twill fabric is higher in comparison to the effect on other fabrics. Bleaching treatment of 10 and 30 minutes duration has resulted in a reduction of tearing strength in warp direction more than in weft direction. Longer bleaching and stone wash treatments cause weakening of the fabric. This may be due to the breakdown of cellulose molecules during bleaching and damaging of surface fibres due to stone washing. It is advisable to avoid finishing processes containing intensive bleaching for longer periods.

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Appendices

Appendix 1: Breaking strength (BS), tearing strength (TS) and specification of fabric samples (F1 – F7) before treatment application

Fabric sample	Composition	Direction	Breaking Strength (Kgf)	Tearing strength (g)
F1- Denim	100% Cotton 3/1(88x60)	Warp	72.6	5333
		Weft	37.89	3242
F2- Drill	98% Cotton,2% Elastane 3/1(80x41)	Warp	103.6	8900
		Weft	31.37	5067
F3- Corduroy	Blue, 98%Cotton,2%Elastane, (42x136)	Warp	25.14	1254
		Weft	17.93	901
F4- Corduroy	White, 99% cotton,1%Elastane (60x96)	Warp	25.75	1439
		Weft	17.58	1970
F5- Twill	White, 99% Cotton, 1%Elastane 2/1(105x48)	Warp	58.00	1612
		Weft	28.65	1488
F6 -Twill	Blue, 100% Cotton 2/1(126x56)	Warp	71.8	2568
		Weft	29.65	2495
F7- Twill	Red,52% Cotton , 48% Polyester 2/1(124x59)	Warp	95.8	3525
		Weft	47.44	2192

Appendix 2: Breaking strength and tearing strength of Denim fabrics after bleaching, sanding and permanganate spray (Given also increase or decrease as percentage)

Treatment		Sandblasting + Permanganate		Bleaching			
Fabric type	Strength	30min	30min	10 min		30 min	
		Warp	Weft	Warp	Weft	Warp	Weft
F1	BS	69.3	35.4	66.2	36.8	47.1	33.4
	TS	5021	2900	5067	3338	2835	3145
F1	BS%	-4.55	-6.57	-8.82	-2.88	-35.12	-11.85
	TS%	-5.85	-10.55	-4.99	2.96	-46.84	-2.99

Appendix 3: Breaking strength and tearing strength of Denim and Drill after stone and enzyme wash treatment as percentage.

Treatment		Stone + Enzyme Wash			
Fabric type	Strength	30min	30min	60min	60min
		Warp	Weft	Warp	Weft
F1 Denim	BS	-29.06	-7.02	-29.06	-12.88
	TS	-18.79	5.49	-30.36	6.48
F2 Drill	BS	-1.45	-3.47	-3.47	-6.60
	TS	9.55	-12.61	-0.56	-18.45

Appendix 4: Increase or decrease of breaking strength (BS) and tearing (TS) of seven fabric samples (F1 – F7) after Enzyme treatments and Garment wash as percentage.

Treatment		Enzyme wash						Garment wash	
Fabric type	Strength	30min	30min	60min	60min	90min	90min	Normal wash time 10min	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
F1	BS%	-13.64	-9.77	-11.16	-17.87	-34.48	-10.27	-11.29	-8.81
	TS%	-11.55	0.96	-4.84	7.71	-12.83	8.42	16.88	23.16
F2	BS%	3.09	-4.43	1.64	-4.65	1.06	-2.52	-5.69	-6.34
	TS%	14.04	-12.57	14.61	-10.52	12.36	-13.80	14.04	-6.22
F3	BS%	-9.07	-23.20	-10.26	-17.51	-11.97	-22.64	-9.59	-15.34
	TS%	24.64	36.51	16.67	32.08	23.68	46.17	16.67	32.08
F4	BS%	-14.52	-10.35	-12.89	-21.05	-12.23	-23.38	-12.23	-13.88
	TS%	12.65	9.39	14.94	-5.23	6.60	-12.54	23.28	27.66
F5	BS%	-18.03	-24.19	-15.00	-15.01	-19.33	-17.52	-22.84	-23.00
	TS%	42.68	71.17	32.69	66.47	29.28	66.53	46.15	67.88
F6	BS%	-23.68	-27.42	-22.56	-19.63	-22.98	-19.29	-24.65	-25.53
	TS%	69.24	4.89	63.36	2.08	58.92	17.92	66.82	5.93
F7	BS%	-8.66	-19.84	-4.38	-20.68	-5.74	-26.75	-13.15	-30.44
	BS%	153.42	143.29	149.65	146.35	153.42	143.29	160.99	143.29

Appendix 5: Changes of TS and BS of twill fabrics after treatments

Treatment		Enzyme wash						Garment wash	
Fabric type	Strength	30min	30min	60min	60min	90min	90min	10 min wash time	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
F5	BS%	-18.03	-24.19	-15.00	-15.01	-19.33	-17.52	-22.84	-23.00
	TS%	42.68	71.17	32.69	66.47	29.28	66.53	46.15	67.88
F6	BS%	-23.68	-27.42	-22.56	-19.63	-22.98	-19.29	-24.65	-25.53
	TS%	69.24	4.89	63.36	2.08	58.92	17.92	66.82	5.93
F7	BS%	-8.66	-19.84	-4.38	-20.68	-5.74	-26.75	-13.15	-30.44
	TS%	153.42	143.29	149.65	146.35	153.42	143.29	160.99	143.29

Appendix 6: Changes of TS and BS of twill fabrics after treatments

Treatment		Enzyme wash						Garment wash	
Fabric type	Strength	30min	30min	60min	60min	90min	90min	10 min wash time	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
	BS%	-18.03	-24.19	-15.00	-15.01	-19.33	-17.52	-22.84	-23.00
F5	TS%	42.68	71.17	32.69	66.47	29.28	66.53	46.15	67.88
	BS%	-23.68	-27.42	-22.56	-19.63	-22.98	-19.29	-24.65	-25.53
F6	TS%	69.24	4.89	63.36	2.08	58.92	17.92	66.82	5.93
	BS%	-8.66	-19.84	-4.38	-20.68	-5.74	-26.75	-13.15	-30.44
F7	TS%	153.42	143.29	149.65	146.35	153.42	143.29	160.99	143.29

Cost effective Fluoride level detector for well water

R. Victor Raj and H. Pasqual*

Department of Electrical and Computer Engineering, The Open University of Sri Lanka, Nugegoda, Sri Lanka.

*Corresponding Author - email: hpasq@ou.ac.lk, Tele: +94112881469

Abstract – *Fluoride is a chemical that humans need at a specified level. The content of fluoride in water varies by region with dry zone generally having higher fluoride level than the average level in wet zone. The fluoride level in well-water will depend on the nature of the rock near the well and the presence of fluoride-bearing minerals. When fluoride levels are above the Maximum Contaminant Level (MCL), health department or local water systems authority must take steps to reduce the amount of fluoride.*

Even though there is a requirement for the government to monitor private wells to assure acceptable water quality, such monitoring in practice does not take place due to logistics issues and the high cost of the monitoring devices. We propose a solution to this problem by introducing a cost effective system that can accurately measure the fluoride content in the water and send such measurement data to a central location for analysis purposes. The system comprises a monitoring device, a communication link and central server that logs data for analysis. The ability to remotely collect data from large number of places would allow a more detailed analysis into the variation of fluoride levels and its underlying causes. This instrument uses the similar analytical method uses in the laboratory where a LED and a photo diode light intensity sensor to determine the concentration of fluoride. A pre-calibrated graph of voltage vs. fluoride concentration is used to detect fluoride level of the water tested.

Keywords: *Fluoride concentration, well water, remote data acquisition*

1 INTRODUCTION

Fluoride is a natural substance that comes from the element fluorine, which is found naturally in rocks and soil. Water passing through the earth absorbs the naturally occurring fluoride and as a result, most water contains some amount of fluoride. Due to the above process, groundwater typically contains more fluoride than surface water. The content of fluoride varies by region with dry zone generally having higher fluoride levels in their water than that of wet zone. Due to the direct impact on human health, there is a need to monitor quality of well water (E.g. Fluoride level). Monitoring of Fluoride concentration in well water poses a challenge due to depth of the well and seasonal changes that occur. Fluoride occurs naturally in most groundwater and as per existing literature, their levels range from 0.1 to 15 parts per million (ppm) [Dissanayake, 2005]. The fluoride level in well-water depends on the nature of the rock near the well and the presence of fluoride-bearing minerals. According to the WHO standards consumption of water with Fluoride concentration above 1.5 mg/l results in acute to chronic dental fluorosis where the tooth colour becomes brown from yellow. This WHO danger level of 1.5 mg/l is not suitable for Sri Lanka as the individual consumption of water in a tropical and humid environment is much higher than that in the more temperate lands. Researchers find this danger level is 0.6 mg /l in the dry zone of Sri Lanka (Dissanayake, 2005). In the context of Sri Lanka, the Maximum Contaminant Level (MCL) then becomes 0.6 mg/l.

Exposure to excessive consumption of fluoride over a lifetime may lead to increased likelihood of bone fractures in adults, and may result in effects on bone leading to pain and tenderness. Children aged 8 years and younger exposed to excessive amounts of fluoride have an increased chance of developing pits in the tooth enamel, along with a range of cosmetic effects to teeth. When Fluoride levels are above the MCL, health department or authorities managing local water systems must take steps to reduce the amount of fluoride so that it is below that level. Since Fluoride is present in virtually all waters at some level, it is necessary to have a mechanism to monitor the level, particularly in well water where higher Fluoride levels can have a severe impact on humans. Testing individual well water quality on a regular basis is important for maintaining a safe and reliable water source. Awareness of water quality allows overcoming specific problems of a water supply through appropriate interventions. This will help to ensure that the water source is being properly protected from potential contamination, and if not appropriate treatment or action can be taken place to avoid health risks. Lack of such mechanism is quite evident today due to higher cost of monitoring devices and also the logistics issues related to manual monitoring mechanism. Neither the government nor the people in affected zones can afford such costly monitoring systems. However, it is important to test the suitability of water quality for its intended use, whether it is livestock watering, or drinking water. Recent advances in electronic and communication through sensor technology have Catalyzed progress in remote monitoring capabilities for water quality. Real-time remote monitoring and sensing technologies becomes a progressively more important tool for evaluating water quality (Glasgow et al, 2004; Storey et al, 2011)

This study proposes a cost effective system that can accurately measure the Fluoride content in the water and send such measurement data to a central location for purpose of analysis. The system comprises a monitoring device, a communication link and central server that logs data for analysis. The ability to remotely collect data from large number of places would allow a more detailed analysis into the variation of fluoride levels and its underlying causes. This instrument uses the similar analytical method used in the laboratory where a LED and a photo diode light intensity sensor to determine the concentration of fluoride.

Various methods have been used for measuring the fluoride content of water samples. The most commonly used methods are Ion Specific Electrode (ISE) method and SPADNS reagent method (colorimetric method). In ISE method, the ion selective electrode incorporates a special ion-sensitive membrane which may be glass, a crystalline inorganic material or an organic ion-exchanger. The membrane interacts specifically with the ion of choice, in this case fluoride, allowing the electrical potential of the half cell to be controlled predominantly by the F- concentration. The potential of the ISE is measured against a suitable reference electrode using an electrometer or pH meter. In the SPADNS method, Fluoride reacts with a dark red Zirconium dye lake to form a colourless complex and another dye. The dye becomes progressively lighter as Fluoride concentration is getting high. This colour change is measured using a colorimeter, simple photometer or by comparing the colour intensity with the colour scale. The SPADNS method is used in this work due to its cost effectiveness and ease of implementation (Burton et al., 1992)

2 METHODOLOGY AND SYSTEM OPERATION

The proposed system complies mainly two sub systems namely Data Acquisition System (DAS) and remote device. Fig. 1 shows the functional block diagram of the proposed system.

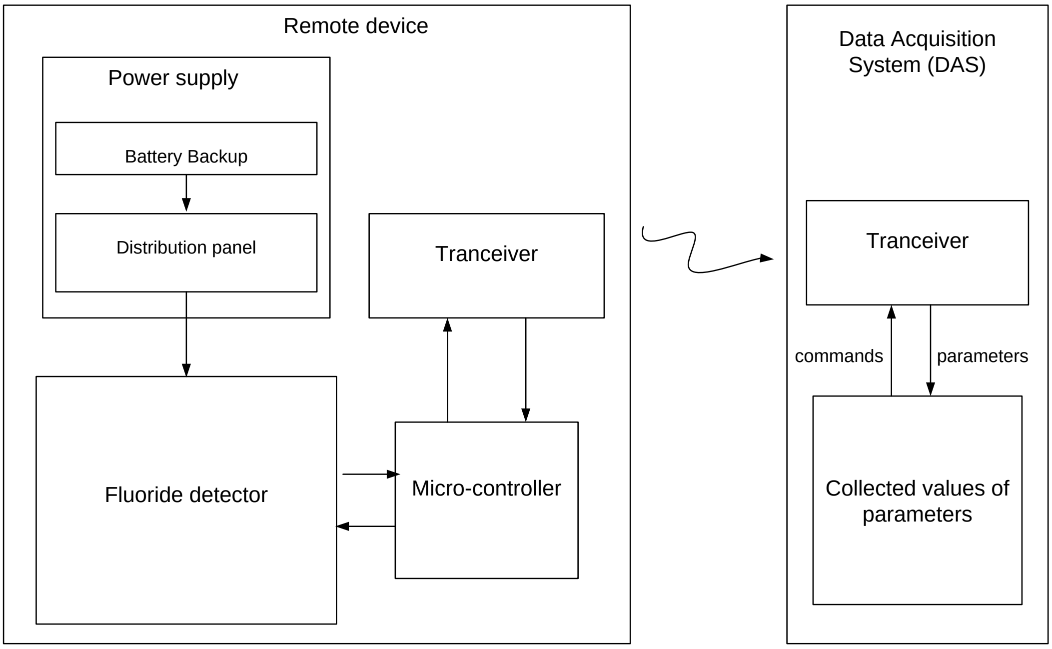

Fig. 1 Functional block diagram of the proposed system

2.1 Data Acquisition System (DAS)

DAS can be considered as the brain of the system. It consists of a PC and a transceiver through which the data of the remote device can be accessed. In this experimental prototype, Bluetooth technology is used for communication link, however it can be easily replaced with a GSM module for expanding the accessibility. DAS has a graphical user interface (GUI) to operate the system. Functions of this DAS are sending commands to the remote device, acquiring data from the remote device and analysis of the received data. When the user clicks on the start button, the program sends the command to the device via the transceiver and waits until it receives the digital signal from the sensing part of the device. These signals are compared with the data included in the system and corresponding values of the parameters are displayed on the GUI. All data can be represented in graphs, data sheets, and references and are saved for future references.

Remote Device

Remote device has 4 main parts, namely, power supply, microcontroller, Fluoride detector and the transceiver. Once the transceiver receives the command signal from the DAS microprocessor sends commands to the Fluoride detector. Once all the processing is completed, results are sent to the DAS via the transceiver. In order to save power, the remote device will go to sleep mode until the next command from DAS is received.

Fluoride detector

The block diagram of the Fluoride detector is shown in Fig. 3. It has four main parts in its operation, namely, Water Pump, Fluoride meter, Colorimeter and Washer. Fluoride detector begins its operation when a control signal is received from DAS. To carry out the Fluoride testing a 10 ml water sample is mixed with a 2 ml Fluoride reagent. A LED and a photo diode light intensity sensor are used to measure the output voltage of the resultant colour which changes with the concentration of fluoride. Using an early calibrated graph of voltage vs. fluoride concentration, the fluoride concentration present in water sample is detected.

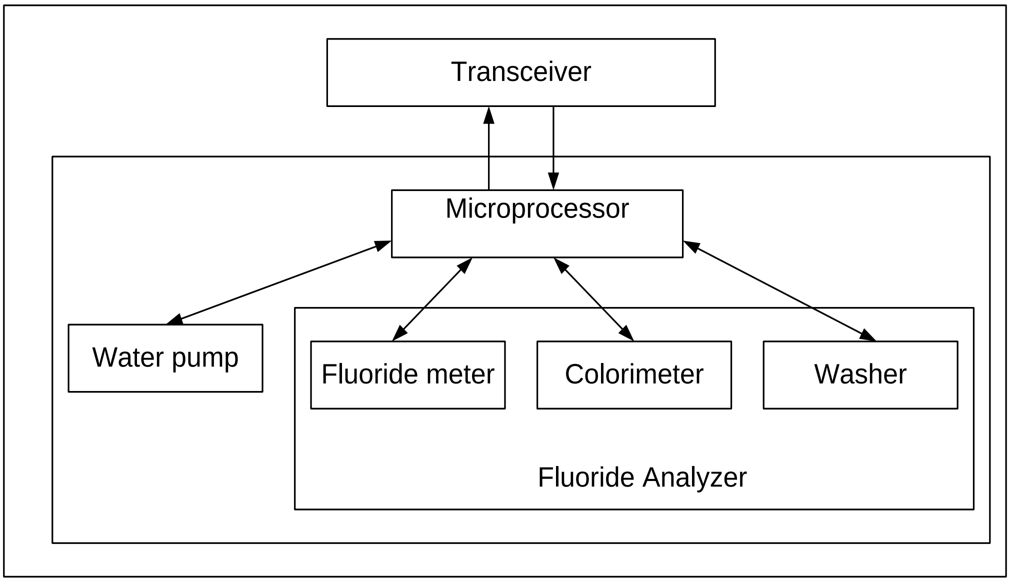

Fig. 2 Block diagram of the Fluoride detector

Automated Fluoride Detection process is as follows: 1. Washing of test tube prior to the collection of water sample. 2. Water sample is taken from the storage to a standard sized (10ml) test tube. 3. Addition of 2ml of fluoride reagent. 4. Passing of light through the solution and detect the output voltage of LDR according to the colour intensity. 5. Transmission of the value to the DAS. 6. Disposing of the resultant water to a safe place. 7. Washing of the test tube fully with the remaining water in the storage.

Light sensing device

Light sensing circuit consists of LED and Photo Diode (Fig. 3). After the reagent is added to the system this circuit is switched on by applying a pulse to the gate of MOSFET. The output intensity of LED will vary according to the colour of the solution. This colour intensity can be identified by a photodiode and a voltage is produced by the circuit. The voltage is proportional to the fluoride concentration.

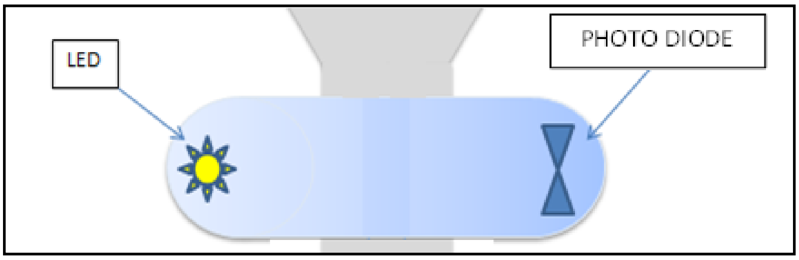

Fig. 3 LED and Photo Diode arrangement in the Light Sensor

Level detectors

A glass funnel is used as the sample collector. Level detector probes and light sensor arrangements are shown in Fig. 4. The outlet of the funnel is fixed with the solenoid valve. The light sensor is fixed to the outer surface. All level detectors are placed inside the funnel. To carry on the fluoride test it is required to mix 10ml of water and 2ml of fluoride reagent. To make sure the reagent is well mixed with water, level detectors are marked at 5ml, 7ml and 12ml levels. Water is filled up to 5ml level and then the reagent is filled up to 7ml level. Finally water is filled again up to 12ml level. These marked levels were detected using timer delays by the microcontroller.

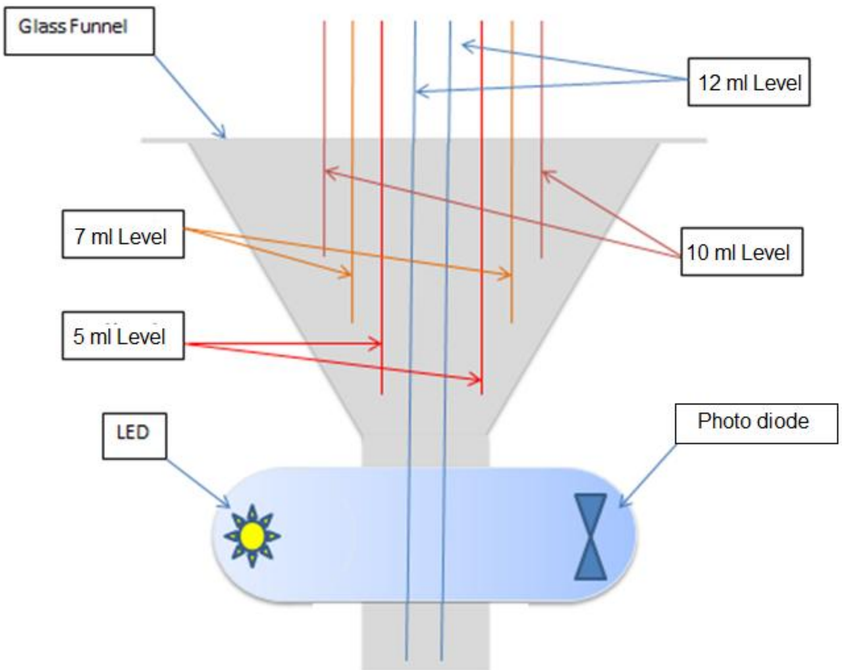

Fig. 4 Level detector probes and light sensor arrangements

Operation of Water Pump

The device can be mounted on the top of the well and it needs a pump to get water from the well or detector can be placed on top of the water level as a floating device. Since the resultant solution has to be safely disposed, the water pumping system is needed and the safest and maintainable way is to have the device fixed on the top of the well. Storage tank volume of the water pumping device is designed to store water to fulfill amount of water required to whole process. Solenoid valves are used to control the water flow and are in normally close position when no current is applied. A simple MOSFET biasing circuit is used to control the valves.

3 TESTING & RESULTS

The prototype was tested under the laboratory conditions. When the LED is switched on, the photodiode detects the intensity of the light and change its resistance resulting in a voltage change in the output of the circuit. To find the output voltage change according to the concentration of the Fluoride, known concentrated NaF solution was prepared. The output voltage vs. the concentration of the fluoride was tabulated in Table 1 while Fig 5 shows the graphical representation.

Table 1 Output voltages of Photodiode circuit for known concentrated NaF solution

Concentration (ppm)	Output Voltages (mV)
0.1	1630
0.2	1110
0.3	1000
0.4	900
0.5	800

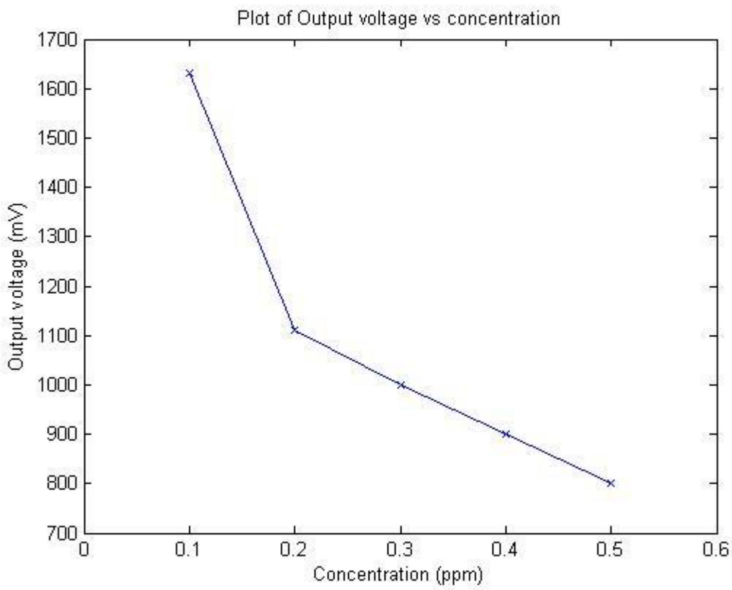

Fig.5 Variation of output voltage vs the known concentration of NaF

Based on the preliminary experiments conducted, the fluoride concentration vs voltage graph appears to be piece-wise linear. More experiments are required to determine the actual relationship between these two parameters.

4 CONCLUSIONS / RECOMMENDATIONS

The research objective of this work was to develop a cost effective mechanism for remote monitoring of Fluoride levels of well water. This paper explains the development of the cost effective fluoride detector with remote data acquisition device. However, more onsite investigations are required to establish the relationship between actual level of Fluoride and the sensor data. Calibration based on highly accurate values from advanced measuring equipment can lead to accurate values from this cost effective device. From a product perspective, only refill cost of reagent is required for the operation after the initial investment and also reuse of the reagent leads to a lower operational cost.

The main advantage of this device is the ability to reuse the hardware as the necessary cleaning happens automatically at regular intervals. A single test requires 2ml of fluoride reagent. Fluoride reagent storing tank can store up to 500ml of fluoride reagent solution. Therefore it is possible to use this detector up to 250 times without refilling the reagent. The solution was designed as an easy to use device from a user point of view. The operation does not require human intervention as this device automatically collects the water sample. Since the collection of sample is automated, the collecting procedure does not change from time to time and thus the standard is maintained. As this tester is attached to a fixed device (Data Acquisition and Measuring Device), testing can be carried out remotely. Time and cost spent for sample collection and analysing is greatly reduced by the remote accessing method and self-operated laboratory procedures. As this device is attached to Data Acquisition and measuring Device, there is no need for manual graph referring, calculation or observations to obtain the results.

Future work

For the trial, a glass funnel available in the market was used as the sample collector. This can be replaced by a good quality less absorption glass so that a higher accuracy can be obtained.

The device can be used to test additional parameters with minor modifications. Some heavy materials are capable of absorbing certain light wavelength (e.g. Fluoride can absorb 580nm yellow light). Hence a relevant wavelength emitting colour LED is required. A multi-colour LED can be used for this purpose. And additional storage of reagent for relevant parameter is required to be added. The same colour intensity sensing arrangement can be used to detect the colour level of the water.

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