Impacts of Climate Parameters on Pavement Service Life at Regional Scale

Pooja V, K C Gouda, Ananda Kumar K R

Abstract— **Weather extremes have major impacts on all road infrastructures and pavement service life. Climate change considerably modifies infrastructure's vulnerability to these impacts. The impacts affect the society and the progress of a country. Also it has an effect on safety of people. Generally, infrastructure is designed on the basis of calculation codes and rules which provide typical intensity values for climatic phenomena associated with a return frequency. While this reference event concept, based on return frequency, has been extremely useful in the past, it is becoming dangerous lately as the underlying assumption that the climate of tomorrow will be similar to that of yesterday is no longer correct.**

According to the National Observatory of the Effects of Global Warming (ONERC), extreme meteorological phenomena will increase in number and degree in the years to come in the metro cities. In this paper we propose a prediction model to show the pattern of pavement service life in response to several weather related changes at a regional scale. The performance analysis of the simulated road parameters are carried out and it shows there is a quite potential scope of the developed model for the analysis of the impact of climate parameters on the pavement service life at regional scale.

Index Terms— **Weather impacts, Road infrastructure, Performance parameters, Pavement condition, Pavement service life.**

I. Introduction

Pavement condition assessment and deterioration estimation is an important part of all pavements and infrastructure management system. They are usually based on models which predict pavement performance based on past and present conditions. However, many difficulties are associated with the measurements and precise estimation of the inputs involved in the performance models, such as traffic flows, environmental condition such as rainfall, temperature etc. The uncertainty in the determination of these and other factors contribute to the difficulties encountered while developing pavement performance models. The implementing organizations have been pointing towards a need for the development of an intelligent pavement performance models that can prioritize pavement maintenance and rehabilitation works. Such models can predict and forecast the pavement service life left and pavement rehabilitation needs and can help in the formulation of pavement maintenance and strengthening programs. Hence there is a need for development of performance of pavement in terms of deterioration. Several works have been carried out for Effect of Pavement Characteristics as described in [1] . A similar work already tested in Taiwan [2] and at Uttaranchal in India [3] on Pavement Condition. Performance Based Rural Roads Maintenance is also studied [4].

The fatigue of the bituminous pavement materials under the repetitive action of traffic loading is one of the major mechanisms of structural weakening of the pavement. Since the fatigue is controlled by tensile strain which reaches maximum at the underside of the bituminous road base of a pavement under traffic loading, it is assumed that fatigue cracking would eventually initiate at the underside of the roadbase and propagates upwards till it reaches the surface. For a pavement structure containing a bituminous surfacing and a bituminous roadbase, this understanding of fatigue weakening means that the roadbase would suffer more fatigue damage than the surfacing, and the more heavily trafficked lane (the nearside lane) would suffer more cracking than the less trafficked lane (the offside lane).

We will be first analyzing the long term multi-source climate data (50-100 years) i.e. temperature, rainfall, wind, humidity etc. over different geographical location (from coastal area to higher altitude area like hill station, from rural area to metro city) to study the trend pattern of the parameters. The road infrastructure data will be analyzed based on the available data (i.e soil type, road age, road type, etc.). The population data and the traffic information will be enabled to know the impact of climate on the road dynamics. All the above mentioned components will be analyzed using the different algorithms to be developed in the present work. Different data base will be developed and integrated in a cloud frame work in the high performance computing environment to analyze the big data. Finally the data mining approach, both statistical and dynamical modelling approach will be adopted for the prediction of the road behavior and the assessment of the impact of climate parameters and climate change on the transport system.

II. Literature Survey

A. Soil types

There are different types of soil in different regions of earth. The moisture retaining property of different types of soils varies from each other. The moisture content of soil is a crucial factor which determines the pavement service life.

I. Sandy

Sandy soil has larger particles compared to other soil types. It's gritty and dry to the touch, and the particles have huge spaces between them.Hence, it can't hold on to water. Water drains away rapidly.

II. Silty

Manuscript received May 2014.

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ISSN: 2278 – 7798

Silty soil has smaller particles than sandy soil and hence it's smooth to the touch. When moist, it's soapy slick. Silty soil retains water for a longer time. Due to its moisture retentive quality, silty soil is cold and drains poorly.

III. Clay

Clay soil has very small particles among the three so it has very good water storage qualities. It's very sticky to touch when wet, but smooth when dry. Little air passes through its spaces due to the tiny size of its particles and its tendency to settle together.

IV. Peaty

Peaty soil is dark brown or black in color, soft and easily compressed due to its high water content, and rich in organic matter.

V. Saline Soil

The soil in extremely dry regions is usually blackish because of its high salt content. The salinity is due to the build up of soluble salts in the rhizosphere.

B. Different types of Road Surfaces

[1] Asphalt Roads

The viscous nature of the bitumen binder allows asphalt concrete to sustain significant plastic deformation, although fatigue from repeated loading over time is the most common failure mechanism. Most asphalt surfaces are laid on a gravel base, which is generally at least as thick as the asphalt layer although some 'full depth' asphalt surfaces are laid directly on the native subgrade. In areas with very soft or expansive subgrades such as clay or peat, thick gravel bases or stabilization of the subgrade with Portland cement or lime may be required. Polypropylene and polyester geosynthetics have also been used for this purpose and in some northern countries, a layer of polystyrene boards have been used to delay and minimize frost penetration into the subgrade. Fig.1 shows asphalt road surface.

Fig.1 . Asphalt Road Surface

[2] Concrete Roads

Concrete surfaces (specifically, Portland cement concrete) are created using a concrete mix of Portland cement, coarse aggregate, sand and water. In virtually all modern mixes there will also be various admixtures added to increase workability, reduce the required amount of water, mitigate harmful chemical reactions and for other beneficial purposes. In many cases there will also be Portland cement substitutes added, such as fly ash. This can reduce the cost of the concrete and improve its physical properties. Fig.2 shows a concrete road surface.

Fig.2. Concrete Road Surface

C. Advantages of Concrete Roadways

Durability and maintenance free life: Concrete roads have a long service life of forty years, whereas asphalt roads last for ten years. Moreover, during this service life concrete road do not require frequent repair or patching work like asphalt roads.

1) Vehicles consume less fuel: A vehicle, when run over a concrete road, consumes 15-20% less fuel than that on asphalt roads. This is because of the fact that a concrete road does not get deflected under the wheels of loaded trucks.

2) Resistant to automobile fuel spillage and extreme weather: Unlike asphalt roads, concrete roads do not get damaged by the leaking oils from the vehicles or by the extreme weather conditions like excess rain or extreme heat.

3) Greener process: Asphalt (bitumen) produces lots of highly polluting gases at the time of melting it for paving. Also, less fuel consumption by the vehicle running on a concrete road means less pollution.

4) Saving of natural resources: Asphalt (bitumen) is produced from imported petroleum, the reserve of which is becoming reduced drastically. On the other hand, concrete (cement) is produced from abundantly available limestone.

III. Design and Methodology of Work

The objective of System Design is the specification of modules and the ways these modules are to be integrated to form a complete module fulfilling its design objectives in the system design.High-level abstraction of the whole module is provided using block diagram.

A. Climate Data Collection

Several climatic parameters like temperature, Rainfall, humidity are studied. The data is collected from Indian Meteorological Department(IMD). Several years of temperature and rainfall data are collected from IMD for the study of the changes in climate over years. Also this data is utilized to project the future climate.

B. Study of the Anthropogenic Factors

The main anthropogenic factor is the growth in population with an exponential growth in the vehicle rate. The traffic

ISSN: 2278 – 7798

data, the rate in the increase of vehicles are studied. The major roads with heavy traffic are listed and the rates of traffic flow on these roads are noted.

C. Road Infrastructure Analysis

Several road types, their construction materials, classification based on surface types are studied. Basically there are two types of roads which are Surfaced roads and Unsurfaced roads. In surfaced roads further classification is made based on the surface type. It is classified into Asphalt roads, Concrete roads and Water Bound Macadem roads. Unsurfaced roads are kacha roads with mud surface. There is no surfacing done for these type of roads. Concrete roads have several advantages over Asphalt roads in terms of durability and service life. But the construction cost of concrete road is very high compared to Asphalt roads. However, it is inevitable to build concrete roads in regions with heavy rainfall to overcome the maintenance expenses.

D. Climate and Data Processing

The raw climate data of several years collected from IMD is processed using HPC systems. Firstly, the data collected is filtered and data of our study region is obtained using our algorithms. Then, the annual average and monsoon average of rainfall is calculated. Also we make an analysis of temperature and calculate the averages of annual temperature and summer temperature. Then anomaly of temperature is also plotted. The graphs for these are shown in the results and discussions chapter. Traffic data of several regions of the city is collected from various sources. The roads with high traffic are studied. Several road parameters such as longitudinal depression, pothole area, and moisture content of the soil are studied. Commercial vehicles per day, Ratio of shoulder, Rainfall, Pot hole area of the roads are studied.

E. Development of Algorithms

Several existing algorithms are analysed and their disadvantages are listed. An efficient algorithm is developed for the analysis of the multi source multi-format climate data. Also the performance parameters of the roads are calculated in the algorithm. Input parameters such as rainfall, temperature, longitudinal depression, pot hole, dry density, bearing ratio, surface cracking, and commercial vehicles per day are considered. Performance parameters such as Drainage Rating, Cracking, Roughness, Edge drop and Rut Depth are calculated.

F. System Design

The system design of the prediction model of the pavement service life is represented in fig 3. The collected climate data, traffic data, road infrastructure data forms the input data set for the prediction model. There are totally five modules in the system which takes inputs such as rainfall, temperature, traffic and road type. These modules calculate drainage rating, rut depth, edge drop, roughness and cracking which are the performance parameters of pavement service life. The output of the modules show graphs to indicate the performance of these parameters throughout the year which in turn is useful in the prediction of the pavement performance and durability. The calculation of these parameters are done at a regional scale considering the features which are specific to that region (for eg. Rainfall is very high in coastal areas).

[1] Drainage Rating : Drainage rating of road is taken as function of Potholes, Shoulder CBR and Field dry density of shoulder.

[2] Edge Drop : An Edge drop is road geometry defect where the vertical distance from the edge to seal the adjacent shoulder exceeds acceptable limit.

[3] Rut Depth : Rutting is longitudinal depression or groove in the wheel track. The ruts are usually of the width of a wheel path.

[4] Roughness and Cracking : Roughness is also observed at all the road sections. MERLIN (Machine for Evaluating Roughness using Low cost Instrument) is used for determination of roughness. Cracking is also observed a Severe distress.

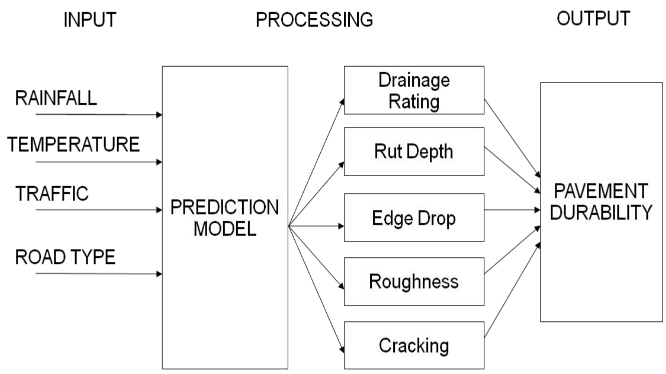

Fig.3. System Design

IV. Results and Discussions

Several years of rainfall data is collected from various sources like India Meteorological Dept and Govt of Karnataka. Average year to year variation of annual rainfall is analyzed and there is much variability in the rainfall for the period 1951-2003 (Fig 4). Similarly, temperature extremes has a lot of effects on the durability of the pavements. Temperature data also collected from IMD and analyzed at daily scale. The annual average temperature is computed and the year to year anomaly in the temperature (deviation from mean) over Bangalore region are presented in fig 5. The trend analysis of both rainfall and temperature is positive but rainfall is marginally increasing (0.006mm/yr) where as the temperature is rising at the rate of 0.2^{o}C/year. As the road infrastructure is mainly dependent on both the parameters i.e rainfall and temperature are used to compute the road related parameters like Drainage rate, Edge depth, Roughness, Rut depth and cracking for Bangalore city and simulated using the standard formula by Atul and Vandana [5] and the results are presented in Fig 6, which shows the variations of performance parameters of a sample road for the January to December months. The results are average of

ISSN: 2278 – 7798

five year simulation.

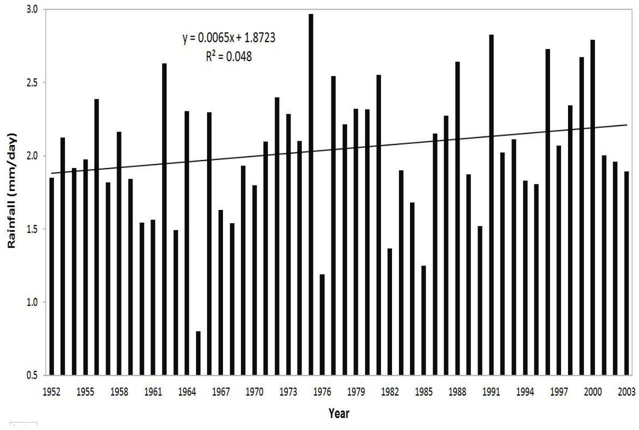

Fig. 4 Annual rainfall trend analysis over Bangalore

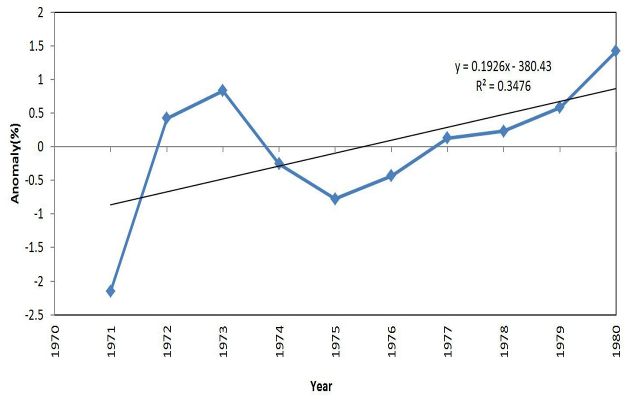

Fig. 5 Annual temperature trend over Bangalore

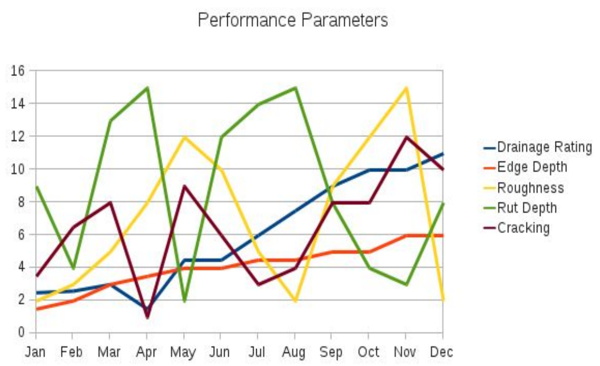

Fig. 6 Simulation of pavement performance parameters over Urban Bangalore roads

V. Conclusion

The main parameters that affect the performance of pavements are Drainage Rating, Rutting, Edge drop, Cracking and Roughness. A few numbers of potholes occur at some parts of the road sections due to poor drainage and construction quality. MERLIN roughness is converted into International Roughness Index in m/km. Performance parameters such as drainage rating, edge drop, rut depth, roughness and cracking have been taken in the study, which mainly depends upon drainage rating, field dry density of shoulder, pothole area, California Bearing Ratio of shoulder & subgrade, edge drop, commercial vehicle per day, rainfall, surface cracking, roughness, longitudinal depression and subgrade moisture content. The performance equations are developed at regional scale considering the main regional factors that affect the pavement service life. The Performance equations developed for different distress types will be used in Pavement Maintenance Management System which will be helpful in prioritization of construction and maintenance works. In future some of this study can be integrated with the type of pavements as suggested in [6] and the performance can be analysed as studied by Alberto and Riggins [7] for the better modelling of the pavement services at regional scale.

Acknowledgment

The first author Pooja V acknowledges to SPARK program of CSIR C-MMACS, HOD Computer Science and Engineering & Principal, SJB Institute of Technology, Bangalore for providing the necessary infrastructures to carry out the work.

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ISSN: 2278 – 7798