## 1.1 GENERAL REMARKS :

Highway engineers have been constantly working for development of a rational method to estimate life of a given pavement through full scale road tests, model studies, laboratory experiments and theoretical analysis. Unlike steel and concrete whose structural properties are well defined, the behaviour of crushed rock, water bound macadam (WBM) and other granular material, etc. is extremely complex and was little understood till about thirty years back resulting in slow progress in the development of rational method to find the relationship between life period of pavements and design thickness of constituent layers.

Flexible pavement design methods in India and many other developing countries are still empirical or semi-empirical, based on past experience with similar subgrades, pavement materials, and traffic loads. These methods are satisfactory as long as the materials, traffic loading conditions and layer thicknesses do not differ from those for which the methods were developed. Because of considerable increase in frequency and intensity of axle loads on Indian roads[1,2,3], coupled with the use of new pavement materials the semi-empirical design methods have become irrelevant.

The field tests have been conducted in this investigation on various National Highways in the Eastern India as a part of the Research Scheme - R6, of the Ministry of Shipping and Transport (Roads Wing), Government of India, entitled 'Development of methods such as Benkelman Beam deflection method for evaluation of structural capacity of existing pavements and also for estimation and determination of overlays for strengthening of any weak pavements'.

Most of the roads in India including a large portion of National Highways have water bound macadam[4,5] (WBM) layers topped with thin bituminous surfacings in the form of premix carpet or surface dressing[6,7].

This thesis concentrates mostly on the study of the performance of some water bound macadam pavements and laboratory evaluation of the properties of the pavement materials in order to predict the serviceable life of a granular pavement.

## 1.2 DEVELOPMENT OF PAVEMENT DESIGN METHODS :

During the last forty years considerable progress has been made in the theoretical approach to the development of fundamental methods of designing road pavements, Burmister[8,9,10], Fox[11] and Hank and Scrivner[12] developed tables and charts of influence values for determining stresses and deflections. Acum and Fox[13], Jones[14] and Peattie[15]

presented tables and graphs for three layer systems. In all these investigations, Poisson's ratio is assumed as 0.5, ~~pertaining~~ to an incompressible body, and influence values have been given for points along the axis of symmetry. Verstraeten[16] gave generalised expressions for determining stresses and deflections in a flexible pavement. Computer programmes like BISAR[17], CHEVRON[18], ELSYM[19], EPAVE[20], MPAVE[20] and NPAVE[20], etc. have been developed by various researchers for analysing stresses and deflections in multilayer pavement. All these computer programmes assume the pavement to be linearly elastic. Duncan, Monismith, and Wilson[21]; Barksdale[22], and Crawford[23] analysed pavements having materials with non-linear structural properties. The ~~se~~ rigorous analytical methods have ~~gone a long way in~~ helped to bridging the gap between the theory and the practice in pavement design.

## 1.3 FULL SCALE ROAD TESTS :

### 1.3.1 Experimental pavements in the United States :

The Bates Experimental Road was the first major test road constructed in Illinois in 1920. For many years, the results of this test road were used as basic data for the design of highways. Between 1923 and 1950 several research projects, which involved construction of test tracks ~~like~~ such as the Arlington Test, Hybla Valley Test, Stockton Test, Lockbourne Air Force Base Test, etc., contributed

to the development of pavement design and construction. The Western Association of State Highway Officials sponsored the WASHO Road Test in 1953-54, which consisted of a number of specially built flexible pavements in Idaho. The object was to investigate the performance of experimental flexible road pavements constructed with a wide range of overall thicknesses and subjected to a known number of repetitions of known axle loads. Construction of test facilities for the AASHO[24] (American Association of State Highway Officials) Road Test began in August 1956. Test traffic was operated from October 15, 1958 to November 30, 1960, with $1.114 \times 10^6$ axle load applications.

1.3.2 The co-operative pavement investigation programme in Canada :

In Canada, the Co-operative Pavement Investigation Programme was started in 1958 by the Canadian Good Roads Association[25] and from 1959 to 1961 extensive pavement inventory data was collected. In the AASHO Road Test and Co-operative Pavement Investigation Programme in Canada, Regression analyses were conducted to relate flexible pavement performance with the principal variables affecting it .

1.3.3 Experimental pavements in Britain :

In Britain the first experiment to investigate the design and performance of road structures as a whole was

laid in 1949, on Trunk Road A., north of Borough bridge, Yorkshire[26]. Among the full-scale flexible pavement tests, The Alconbury Hill experiment (flexible sections) can be regarded as typical.

1.3.3.1 The Alconbury Hill experiment[27] :

The flexible sections of the Alconbury Hill experiment were opened to traffic in November 1957, and involved about 2km of the north bound carriage way of Trunk Road A.1 in Cambridgeshire. The experiment consisted of 33 flexible sections approximately 60 m in length. In 1957, total daily commercial traffic was 4000 vehicles, in both directions. The CBR of the soil was between 3 and 5 per cent. The main objectives were :

(1) To compare the behaviour of five roadbase materials (wet-mix slag, rolled asphalt, lean concrete, open-textured tarmacadam and soil-cement) under a 100 mm rolled asphalt surfacing and to determine the appropriate thickness of each in relation to the traffic carried.

(2) To investigate the effect of type and thickness of surfacing on the lives of pavements using the same roadbases.

(3) To investigate the effect on life of the thickness of the sand sub-base used.

The main criterion used to assess the relative performance of the flexible pavements ~~is the~~ was deformation ~~measured~~ transversely across the road, caused by the passage of the traffic. Non-destructive testing techniques including the deflection beam and wave velocity methods were used throughout the life of the road. Mean transverse profiles ~~have been~~ were plotted at four levels of traffic for the rest test ? sections with wet-mix roadbases, and graphs ~~have been~~ were plotted ~~between~~ relating permanent deformation (rutting) and observed or estimated cumulative standard axles for all ~~the~~ sections ~~concerned~~.

## 1.4 NEED FOR PRESENT STUDY :

A highway engineer in India does not know how long ~~his~~ water bound macadam road ~~could~~ will last before the pavement requires a major resurfacing. He is not in a position to predict ~~find~~ the remaining life of granular pavement where as the engineers in the U.S.A. and U.K., and ~~many~~ other developed countries are in a better position to estimate the remaining pavement life in their respective regions because of the scientific study of several full scale road tests. The present research attempts ~~to make a~~ systematic ~~study of~~ has been undertaken several granular pavements in Eastern India so that a formulation can be made to estimate the life of the granular pavements accurately. The test sections are located on various National Highways in

Orissa, Bihar and West Bengal.

1.5 SCOPE OF THE PRESENT INVESTIGATION :

The present investigation aims at finding the life period of full depth granular pavements. Benkelman Beam deflections, rutting, cracking and patching are measured on different test sections for calculating the performance of the pavements. A repeated load test apparatus is fabricated[28] in the laboratory for testing the subgrade soils and water bound macadam base for determining the elastic moduli under repeated triaxial stress conditions. A finite element programme is developed for determining stresses and strains in the pavement layers for correlating the pavement performance and the critical stress and strain values. More specifically the objectives of this thesis may be summarised as follows :

1. to review the various analytical methods and experimental techniques for analysing the pavements,

2. to develop a computer programme for analysing elastic layered flexible pavements by finite element method,

3. to develop a suitable laboratory equipment for applying desired repetitive load to subgrade soils and aggregate materials,

4. to find a test procedure for evaluating the resilient modulus characteristics for subgrade soil and aggregate material samples under repeated triaxial stress conditions,

5. to determine a procedure for predicting the pavement deflections and subgrade vertical strains by iteration technique, using the computer programme and the experimental elastic parameters,

6. to check the validity of the procedure for predicting ~~prediction of~~ pavement deflections by comparing the computed deflections with the measured deflections at several ~~places~~ locations on National Highways in Eastern India,

7. to develop a relationship ~~among~~ between rut depth, vertical subgrade strain, and cumulative number of standard axles,

8. to find the relationship between laboratory C.B.R. (at field density and in-situ moisture content) and resilient modulus for subgrade soils, and

9. ~~finally~~ to ~~find~~ determine the pavement life for the test sections from the relationship developed ~~among~~ between rut depth, subgrade vertical strain, and cumulative number of standard axles.

~~A glance at the table of contents is sufficient to reveal the presentation of the remaining portion of the thesis.~~ ~~The second chapter~~ Chapter II is devoted primarily to a review

and analysis of previously conducted investigations having special relevance to the objectives of the present investigation. Chapter III briefly describes the development of the computer programme. Development of experimental set-up in the present investigation is described in Chapter IV. Procedure for testing subgrade soil samples with the results are ~~given~~ summarized in Chapter V, and procedure for testing aggregate samples with the results are ~~shown~~ contained in Chapter VI. Details of field pavement tests and data collection are explained in Chapter VII. Chapter VIII contains the analytical procedure for predicting the pavement deflections and subgrade vertical strains. Determination of life period of pavement structure and development of relationship between (i) average rut depth and surface deflection and (ii) average rut depth and total area of cracking and patching with discussions are explained in Chapter IX. Conclusions drawn and scope for further investigations have been summarized in the final chapter.