INTRODUCTION

1.1 General

The importance of having a proper road network for the development of the country was realised quite early in India. The first road development plan known as Nagpur Plan (1941-1961) highlighted the long-term road infrastructure requirements of the country and classified the road network into a functional hierarchy comprising National Highways, State Highways, Major District Roads, Other District Roads and Village Roads. Out of these, the Other District Roads (ODRs) and Village Roads (VR) were categorized as Rural Roads. ODRs are feeder roads serving the rural areas where agriculture is the predominant occupation, providing outlets to urban market centres. These low volume roads play a significant role in the development of backward areas and in accelerating the socio-economic development of the country.

During subsequent road development plans also, rural roads have received significant attention and emphasis. A number of programmes such as the minimum needs programme (MNP), National Rural Employment Programme (NREP), Rural Landless Employment Guarantee Programme (RLEGP) and Jawahar Rozgar Yojana (JRY) were launched to achieve the goal of rural connectivity. In the recent past, the ministry of rural development, Government of India, has launched a massive road-building program called the Pradhan Mantri Gram Sadak Yojna (PMGSY) for connecting the unconnected villages with all-weather roads with an outlay of about 130,000 crores rupees (26 billion USD) (PMGSY, 2009a). Conventional flexible pavements consisting of granular sub-base and base with a thin wearing course of bituminous layer are commonly adopted for rural roads. These roads require frequent maintenance due to the damage caused by overloaded vehicles and poor drainage conditions prevailing in villages. In the absence of adequate fund and timely maintenance, the serviceability level of the roads deteriorates rapidly.

Traditional method of flexible pavement construction adopted in India involves the use of granular layers with or without surfacing. The thick layers of granular base and subbase use significant quantities of aggregates. Many states in India face the problem of scarcity of road quality aggregates. Cost of aggregates continues to escalate due to restrictions imposed on the quarrying industry from environmental considerations. In many places, carriage cost of aggregates is very high resulting in high cost of construction of roads. It is, therefore, necessary to explore alternate types of pavements that can be constructed using locally available materials and which require less maintenance.

The full-scale tests conducted by Mitchell et al. (1979) at U.S. Army Engineer Waterways Experiment Station (WES) have shown that interconnected shallow, thin-walled plastic cells placed over a soft subgrade and filled with sand can provide significantly greater load-carrying capacity than can be provided by the compacted soil alone. Cowland and Wong (1993) reported the performance of the geocell mattress laid over soft subgrade. The geocell mattresses performed satisfactorily as foundations for the embankment constructed on the soft clay. Construction and performance of the geocell mattress have also been reported by Bush et al. (1990).

A surface course of cell-filled concrete was developed in South Africa (Visser, 1994, Visser and Hall, 1999). The concept of cell-filled concrete pavement, pioneered by Visser and Hall appears to be very promising for low-volume roads. The pavement developed in South Africa (Visser,1994, Visser and Hall, 1999) consisted of (i) spreading a formwork of cells of plastic sheet held under tension over a compacted base (ii) filling the cells with single size aggregates (iii) compaction of aggregates and (iv) grouting of aggregates with cement-sand mortar. In another type of construction, self-compacting concrete was used (Visser and Hall, 2003) for making cell-filled concrete. Due to the flexibility of the cast-in-situ concrete block, such pavement is termed as flexible-concrete pavement (Visser and Hall, 1999). The size of each cell is usually 150 mm × 150 mm with the depth of cell varying from 50 mm to 150 mm depending upon the traffic load. The cells are stretched along the carriageway and tensioned by using steel pegs and filled up with a suitable pavement material and compacted using a roller. Figure 1.1 shows the schematic arrangement of a formwork of cells stretched over a base. During compaction, cell walls deform providing interlocking vertical joints between adjacent blocks as illustrated in Figure 1.2.

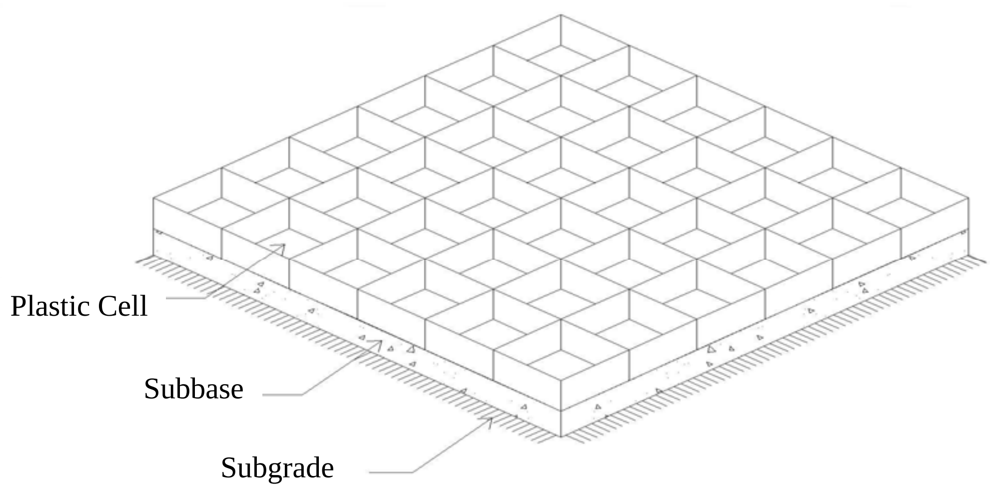

Figure 1.1: Schematic arrangement of plastic cell formwork

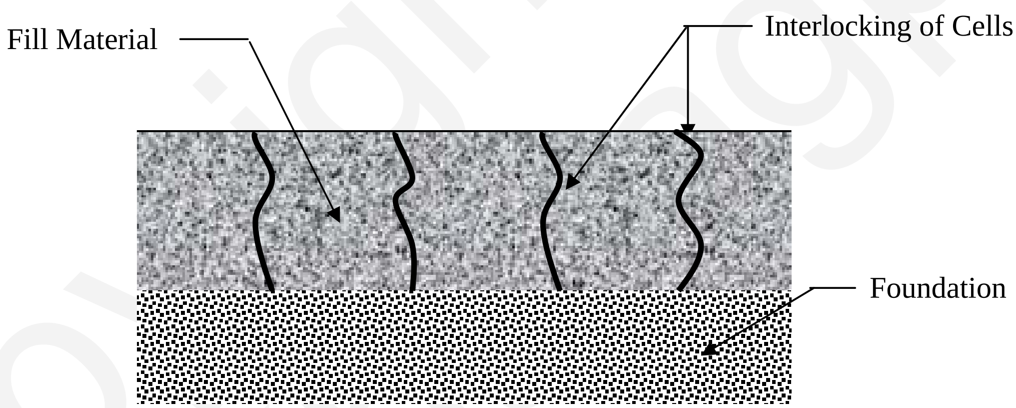

Figure 1.2: Schematic representation of deformed plastic cells

A cell-filled pavement was built in April 2004 on an experimental basis at Rakhal Garia, a village situated 10 km from IIT Kharagpur. Length of the pavement is 250 m. Thickness of the cell-filled layer is 100 mm. Usually four to five trucks carrying stone chips, sand, and bricks operate on the road daily. The pavement has already served for six years and it is still in a sound condition without any maintenance. FWD test conducted on this pavement gave modulus values between 3500 MPa to 5000 MPa for the cell concrete layer. Performance of the road clearly indicates that the cell-filled technique is a very promising alternative to the traditional pavements for low volume roads.

Ryntathiang et al. (2005) conducted laboratory evaluation of cell pavements having grouted concrete and ready mix concrete. Evaluation of test tracks using a FWD resulted in backcalculated moduli of the cell pavement layer in the range of 1750 MPa to 2540 MPa. Pandey (2006, 2007) also explored the feasibility of using the concept of cell-filled concrete pavement for village roads. All the model pavements had granular subbase.

1.2 Need for the Present Study

Considering the potential of the technique of cell-filled pavement construction and also the concern about scarcity of aggregates at many locations, it is essential to examine the feasibility of adopting cell-filled pavement technique in rural roads. Most of the earlier investigations on cell-filled pavement were limited to cell-filled concrete pavement laid over granular base. It is, therefore, necessary to investigate cell-filled pavement constructed with different types of materials such as cement, sand, soil, laterite boulder and moorum in the subbase layer. The present study aims at investigating cell-filled pavement layers laid over different types of subbases.

1.3 Objective and Scope of the Work

In the light of the discussion presented in the preceding paragraphs, the broad objective of the present work is to carryout experimental and numerical studies to gain insight into the performance of cell-filled pavements constructed with different materials and laid over different subbases. For realising the objectives of the present work, the following scope has been selected.

- Construction of test sections, each of 2.5 m × 2.5 m size, with different combinations of cell-filled pavements.
- Structural evaluation of cell-filled pavement test sections using Falling Weight Deflectometer (FWD) and Benkelman beam deflection methods.
- Performance evaluation of cell-filled pavement sections under accelerated loading condition.
- Development of a FEM based model for analysis of cell-filled pavements.
- Development of guidelines for selection of equivalent modulus for cell-filled layer for use in linear elastic layered analysis.

1.4 Organization of the Thesis

- The first chapter gives the introduction to the research work.
- The second chapter deals with the review of literature related to cell-filled pavements.
- Experimental investigations carried out and the methods adopted for construction of cell-filled pavements are discussed in chapter three.
- Chapter four gives the details of the structural evaluation carried out on the cell-filled test sections. Results of backcalculated elastic moduli of pavement layers, performance evaluation of test sections are also presented in this chapter.
- Development of FEM model for cell-filled pavements is presented in fifth chapter.
- Chapter six contains the methodology for design of cell-filled pavement, development of design charts and details of cost analysis of cell-filled, conventional flexible and rigid pavements.
- Conclusions drawn from the present investigation are discussed in chapter seven.