PAVEMENT DESIGN USING GEO-TEXTILES

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Abstract: The purpose of this project is control the position of pavement by using Geo-textile either extend the service life of the pavement or to reduce the total thickness of the pavement system. However, the economic benefits of using this material are still not clear. In general, most of the geo-textile related life cycle cost analysis studies only account for agency costs and their durability. In this study, a comprehensive life-cycle cost analysis of geo-textile stabilized pavements, including initial construction, drainage, future maintenance, rehabilitation, and user costs is considered.

A comprehensive economic life cycle cost analysis framework has been developed in this study in order to evaluate the economic benefit of using geo-textiles in pavement design. The resulting benefit has been quantified in terms of a cost-effectiveness ratio and durability. The findings in this study are limited to the design features, unit costs, drainage facilities and performance models assumed in this analysis.

***Key Words* - Geo-textiles, Economical Benefits, Survivability, Drainage Facilities, Sediments control.**

1. INTRODUCTION

1.1 Scope

This course covers physical properties, functions, design methods, design details and construction procedures for geo-textiles as used in pavement design and drainage applications. Geo-textile functions described include pavements, filtration and drainage. This course does not cover the use of other geo-synthetics such as geo-grids, geo-nets, geo-membranes, plastic strip drains, composite products and products made from natural cellulose fibers.

1.1.1What is a geotextile?

A geo-textile is a class of industrial textile that is composed of polypropylene or polyester resin that have yarns that are woven, knitted, needle punched, or thermally or chemically bonded to form a flat permeable sheet. Carpet backing, car trunk liners, trampolines, swimming pool covers are other types of industrial textiles. These are a kind of geo-synthetic material that has become more and more popular since last fifteen years. It has more than 80 applications to a significant extent to its resistance to biodegradation. Geotextiles are indeed textiles, however not in the traditional sense of the word. They are no natural materials like cotton, wool or silk. Geotextiles are synthetic fibers that can be made into a flexible, porous, nonwoven needle felt fabric.

1.1.2 Why Geo-Textiles?

Easy installation. Does not require costly equipments for its application. Reduces the total thickness of the pavement system. It increases the life and reduces the cost of maintenance. The quality of the product can be controlled hence it is industries made. Can be easily made from local materials. It does not require skilled labours.

1.2 Geo-textile Components and Classification

1.2.1 Materials

Geo-textiles are made from polypropylene, polyester, polyethylene, polyamide (nylon), polyvinyl chloride, and fiberglass. Polypropylene and polyester are the most used. Sewing thread for geo-textiles is made from Kevlar or any of the above polymers. The physical properties of these materials can be varied by the use of additives in the composition and by changing the processing methods used to form the molten material into filaments.

1.2.2 Geo-textile Manufacture

1.2.2.1 In woven construction the warp yarns, which run parallel with the length of the panel (machine direction), are interlaced with yarns called fill or filling yarns, which run perpendicular to the length of the panel .Woven construction produces geo-textiles with high strengths and moduli in the warp and fills directions and low elongations at rupture. The modulus varies depending on the rate and the direction in which the geo-textile is loaded. When woven geo-textiles are pulled on a bias, the modulus decreases, although the ultimate breaking strength may increase.

1.2.2.2 Manufacturers literature and textbooks should be consulted for greater description of woven and knitted geo-textile manufacturing processes which continue to be expanded.

1.2.2.3 Nonwoven geo-textiles have been extensively for filtration, separation and drainage function and also to form moisture proof barrier. There is a phenomenal increase abroad in the use of non woven geo-textiles for function. The fibers are generally oriented randomly within the plane of the geotextile but can be given preferential orientation. In the spun-bonding process, filaments are extruded, and laid directly on a moving belt to form the mat, which is then bonded by one of the processes described below.

- **Needle punching:** Bonding by needle punching involves pushing many barbed needles through one or several layers of a fiber mat normal to the plane of the geo-textile. This process causes the fibers to be mechanically entangled in form of mat.
- **Resin bonding:** Resin is introduced into the fiber mat, coating the fibers and bonding the contacts between fibers.

• **Combination bonding:** Sometimes a combination of bonding techniques is used to facilitate manufacturing or obtain desired properties.

• **Heat bonding:** This is done by incorporating fibers of the same polymer type but having different melting points in the mat, or by using hetero filaments, that is, fibers composed of one type of polymer on the inside and covered or sheathed with a polymer having a lower melting point.

1.2.2.4 Composite geo-textiles are materials which combine two or more of the fabrication techniques. The most common composite geo-textile is a nonwoven mat that has been bonded by needle punching to one or both sides of a woven layer.

1.3 Durability of Geo-Textiles

Exposure to sunlight degrades the physical properties of polymers. The rate of degradation is reduced by the addition of carbon black but not eliminated. Polymer material becomes brittle during cold temperatures. Chemicals in the groundwater can react with polymers. All polymers gain water with time if water is present. High pH water can be harsh on polyesters while low pH water can be harsh on polyamides. All the discussed factors should be considered while selecting the geo-textiles and its varieties for the best performance.

1.4 Geo-textile Functions and Applications

Geo-textiles have different properties, applications and functions depending upon their physical properties, mechanical properties, hydraulic properties, degradation properties and endurance properties etc. Some of them are listed below.

1.4.1 Filtration:

The geo-textile openings should be such that to prevent soil particle movement. It also serves the function of traditional granular sizes filter. Both the geo-textile and granular filter must allow water, moisture and gas to pass without significant buildup of hydrostatic pressure. Example - A geo-textile-lined drainage trench along the edge of a road pavement. The ease with which water, moisture and air can infiltrate or seep into the ground is known as permeability. (Fig. 1) .

1.4.2 Drainage: This refers to the ability of thick nonwoven geotextile whose three-dimensional structure provides an avenue for flow of water through the plane of the geotextile. also illustrates the transmissivity function of geotextile. Here the geotextile promotes a lateral flow there by dissipating the kinetic energy of the capillary rise of ground water. When functioning as a drain, a geo-textile acts as a conduit for the movement of liquids or gases in the plane of the geo-textile. Examples are geotextiles used as wick drains and blanket drains. (Fig. 2)

1.4.3 Reinforcement: This is the synergistic improvement in the total system strength created by the introduction of a geotextile into a soil and developed primarily through the following three mechanisms:

1. Membrane type of support of the wheel loads. 2. Lateral restraint through interfacial friction between geotextile and soil/aggregate. 3. Forcing the potential bearing surface failure plane to develop at alternate higher shear strength surface. (Fig. 3)

Fig.1 (Google)

Fig. 2 (Google)

Fig. 3 (Google)

1.4.4 Separation: Geotextiles will prevent two soil layers of different particle sizes from mixing with each other. Separation is defined as, "The introduction of a flexible porous textile placed between dissimilar materials so that the integrity and the functioning of both the materials can remain intact or be improved". In transportation applications separation refers to the geo-textile's role in preventing the intermixing of two adjacent soils. For example, by separating fine subgrade soil from the aggregates of the base course, the geotextile preserves the drainage and the strength properties of the aggregate material. (Fig. 4)

1.4.5 Sediment Control: A non-woven geotextile performs this function when impregnated with asphalt or other polymeric mixes rendering it relatively impermeable to both cross-plane and in-plane flow. The classic application of a geotextile as a liquid barrier is paved road rehabilitation. Here the non-woven geotextile is placed on the existing pavement surface following the application of an asphalt tack coat. The geotextile absorbs asphalt to become a waterproofing membrane minimizing vertical flow of water into the pavement structure. (Fig. 5)

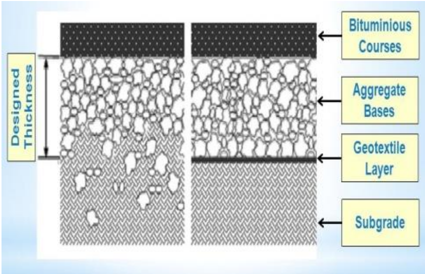

Fig.4 (Google)


Fig.5 (Google)

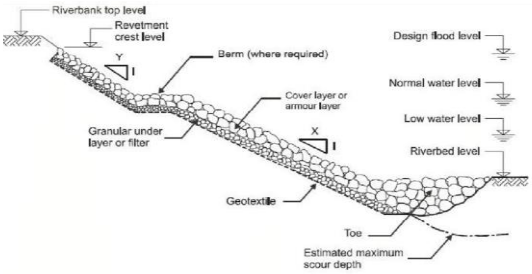

Fig.6 (Google)

1.4.6 Erosion Control: Geo-textile protects soil surfaces from the tractive forces of moving water or wind and rainfall erosion. It can be used in ditch linings to protect erodible fine sands or cohesion less silts. It is placed in the ditch and is secured in place by stakes or is covered with rock or gravel to secure the geo-textile, shield it from ultraviolet light, and dissipate the energy of the flowing water. It is also used for temporary protection against erosion on newly seeded slopes. After the slope has been seeded, the geotextile is anchored to the slope holding the soil and seed in-place until the seeds germinate and vegetative cover is established.(Fig. 6)

1.4.7 Applications: It can be used for roads and railways, landfills and stone base courses, earth structures, sidewalks and sand drainage layers, green areas and recreational facilities, filtration system, duct banks and pipe trenches hydraulic works, retaining wall structures and many other applications. The basic principles of incorporating geotextiles into a soil mass are the same as those utilized in the design of reinforced concrete by incorporating steel bars. The woven fabrics or non-woven are used to separate the soil from the sub-soil without impeding the ground water circulation where ground is unstable. The fabrics are used to provide tensile strength in the earth mass in locations where shear stress would be generated. Unpaved and paved roads in airport runways.

2. LITERATURE REVIEW

2.1 P. B. Ullagaddi, T.K.Nagaraj presented an **"Investigation on geo-synthetic reinforced two layered soil system"** which says that investigation has been carried out with different thickness configuration of the two soils and three types of woven and non-woven geotextiles, having different physical and mechanical properties**.** Based on experimental work it infers that there is improvement in CBR Value and therefore increases bearing capacity. Due to increase in bearing capacity, thickness of soil layer can be reduced to serve the same functioning. Based on U.S .corps and IRC method, woven geotextile found to be more effective in increasing CBR value than non-woven geotextile.

2.2 Sarika B. Dhule and S.S.Valunjkar (2011) presented an "**Improvement of flexible pavement with use of geo-grid"** which says that Geogrid +murrum –increase CBR value and factors affecting the compaction characteristics are shear strength and low permeability. CBR value depends upon degree of compaction.

2.3 A.K.Choudhary, K.S.Gill and J.N.Jha (2011) presented on "**Improvement in CBR values of expansive soil sub-grades using geo-synthetics"** which says that expansion ratio decreases when number of reinforcing layer is increased.CBR value increases by increasing number of reinforcing layer. Reinforcing efficiency: Geo-grid better than jute geo-textile.

2.4 K. Rajagopal, S. Chandramouli, Anusha Parayil & K. Iniyan presented a **"Studies on Geosynthetic reinforced road pavement structures"** which says that by using geo synthetic material there is improvement in strength and stiffness and shows better performance under repeated loads(fatigue condition).Under monotonic loading, modulus improvement factor is higher.

2.5 Vaishali S. Gor L. S. Thakur Dr. K.R. Biyani presented a "**Study of typical characteristics of expansive subgrade with geotextiles and cushion materials"** which concludes that by Addition of metakaolin, swelling pressure of black cotton soil reduces but further increment in the amount of meta kaolin results in increase in swell pressure. Increase in unconfined compressive strength has been noticed. Stabilised metakaolin expansive soil CBR value is higher compared to expansive soil without metakaolin.

2.6 R. Ziaie Moayed and M. Nazari studied the "**Effect of Utilization of Geosynthetic on Reducing the Required Thickness of Sub base Layer of a Two Layered Soil"** which says that by inclusion of geogrid improves the shear resistance at the interface by offering interlocking resistance and reduce the lateral movement of the soil. It also offers more separating function and prevent the sand layer entering into the underneath layer (clayey soil)

2.7 Ambika Kuitya, Tapas Kumar Roy presented a **"Utilization of geogrid mesh for improving the soft subgrade layer with waste material mix composition"** which says that by insertion of geogrid –provides better resistance against loading and also CBR value increases significantly at soaked condition. Inserting geogrid at one third height found to be optimum height and improves bearing capacity.

2.8 Dr. P .senthil kumar and R .Rajkumar studied about "Effect of Geotextile on CBR Strength of Unpaved Road with Soft Subgrade" which concludes that it's more advantageous for unpaved road and provide more resistance at lower penetration. It also enhances CBR value.

2.9 Dr. S. K. Chaudhary Assistant presented the **"Geotextiles in Road Construction, Maintenance and Erosion Control"** Permeability should also always be considered in separation uses to allow moisture to move freely through the system. This avoids excessive hydrostatic pressures which cause soil failure. Most geotextile system failures result from improper installation, improper selection of fabrics, a change of conditions from the original design.

2.10 Dr. Bipin J Agrawal presented the **"Geotextile: It's Application To Civil Engineering – Overview"** Textiles are not only clothing the human body but also our mother land in order to protect her. Extensive awareness should be created among the people about the application of geotextiles. Geotextiles are effective tools in the hands of the civil engineer that have proved to solve a myriad of geotechnical problems.

2.11 Haresh D. Golakiya, Chandresh H. Solanki studied the **"Geotechnical Properties Of An Old Waste Dumpsite: A Case Study Of Surat"** From the present study it is found that waste fill material is heterogeneous in nature with variations in various geotechnical properties. In present paper geotechnical properties of the waste dump site is evaluated. Geotechnical properties of waste fill material is site specification it varies from site to site. Site also content spots of loose pockets at random palace in plan and elevation. The average mean value of water content is approximately 17 %. The statistical mean value of six random sample is found to be 1.28 gm / cc. Type of fill when compared to soil, it is found in most of random sample that soil is SC – CL to ML having good value of dry density.

2.12 Sayali V Paygude, Priyanka S Dhumal presented the **"Review On Geotextiles In Road Construction"** Geotextiles effectiveness depends upon the strength of the fabric and proper installation. Geotextiles are a cost effective way to insure better drainage & stabilization of sub grades. Hence it can be concluded that use of geotextile in road construction is very effective if proper care is taken and is a material which is here to stay.

3. RESEARCH METHODOLOGY

3.1. Use of Geotextile in Pavement Sections.

3.1.1 Description: Follow installation guide for placing a geotextile between base or sub-base or base and subgrade for any of the following applications • Base or Sub-base Separation • Base or Sub-base Stabilization • Base or Sub-base Capillary Barrier • Base or Subbase Reinforcement Do not place geotextiles when weather conditions, in the opinion of the engineer, are not suitable to allow placement or installation. This will normally be at times of wet conditions, heavy rainfall, extreme cold or frost conditions, or extreme heat. Location of geotextile in Pavement Structural Section applications

3.1.2. Materials and Storage Requirements: Geotextile shall meet the material requirements of propose. Cover and elevate geotextile rolls during storage to minimize potential damages before installation and to protect them from the following:

• Site construction damage (tearing, excessive mud, wet cement, epoxy, etc.); • Precipitation; • Extended ultraviolet radiation including direct sunlight; • Chemicals that are strong acids or strong bases; • Temperatures above 160 °F and below -22 °F. Do not leave geotextiles which have not been ultraviolet stabilized uncovered for longer than 7 days after the installation. Do not expose ultraviolet stabilized materials longer than 14 days after installation.

3.1.3. Equipment: Use mechanical or manual lay down equipment capable of handling full rolls of fabric and laying the fabric smoothly, without wrinkles or folds. The equipment shall be in accordance with the fabric manufacturer's recommendations or as approved by the engineer.

3.1.4. Installation: Follow the following steps to place a geotextile in the pavement structural section: A. Surface Preparation. Prepare the installation site by clearing, grubbing, and excavating or filling the area to achieve the design grade:

a. Remove topsoil and vegetation.
b. Identify soft spots and unsuitable areas.
c. Excavate and backfill the soft spots and unsuitable areas with select materials.
d. Compact the backfilled area using engineered procedures, as directed.

Installed properly, these materials stabilize stone bases. The four basic steps involved in placing geotextiles:

3.2. Sub grade preparation: The design of a pavement is overall responsible for strength and performance is dependent not only upon its design (i.e. mix design and structural design) but also on the bearing load capacity of the soil subgrade. Thus, anything that can be done to increase the bearing load capacity (or structural support) of the soil subgrade will most likely improve the pavement load-bearing capacity and as well as pavement strength and performance (Fig. 7). Moreover, greater subgrade quality can result in thinner (but not excessively thin) and very economical design of pavement. Lastly, these finished subgrade should meet requirements, grades and slopes specified for the best design. These subsection covers following

- Final durable coats (i.e. prime coats) for Hot Mix Asphalt pavements
- Improving subgrade support by compaction
- Subgrade elevation
- Different subgrade preparation practices
- Improving subgrade support by alternative means

Fig.7 (Google)

Fig.8 (Google)

3.3. Geotextile placements: Open and Unroll the geotextile and place it in intimate contact with the subgrade soil, without wrinkles or folds, on the prepared subgrade. Place the geotextile in the direction of construction traffic. Remove wrinkles and folds not associated with roadway curves by stretching and staking as required. Overlap adjacent geotextile rolls. Secure the overlapped area by sewing or joining as required in the plans. Regardless of sub grade strength, the pavement site should be cleared of all sharp edge objects, tree stumps, large stones etc that could puncture the fabric. Unless it is necessary to achieve final grade, the biodegradable material need not be removed, because it can provide extra support during aggregate placement until final compaction. Cushion layers under the nonwoven fabric are usually necessary, since the fabric prevents soil fines from pumping into the aggregate layer. Geotextiles should be rolled out onto the sub grade by two people, beginning at a point that allows easy access for construction equipment. (Fig.8)

Fig.9 (Google)

Fig.10 (Google)

3.4. Aggregate placements: The strength of the natural subgrade below is often not durable enough to suit long term pavements. To overcome this deficiency, limestone aggregate bases generally granular in nature and with good grade are placed and compacted mechanically to increase their ratio(i.e. density). The overall finished product is a durable, uniform, and long term substrate and base for the support of the pavement section and traffic above (Fig.9). If deemed suitable for soil type/condition, the subgrade is graded, shaped, and compacted prior to aggregate base. Grade is the size and amount of coarse as well as fine aggregate which make up an aggregate base material. For mass aggregate placement, the typical crew will consist of a foreman, a laborer, and 1-2 operators. The most common order of operations is :

- Rough and normal placement of aggregate with dozer.
- Further grading of aggregate by grader.
- Roll and compact the aggregate material
- Repeat it for multiple times.
- Fine grade with grader and or with smaller equipment (skid steer loader, handwork)
- Roll as well as compact for one last time.

3.5. Aggregate compaction: Compaction is the process by which the volume of air in pavement layer is reduced by using external forces to reorient the constituent aggregate particles into a more closely spaced arrangement. This reduction of air volume produces a corresponding increase in aggregate density (Fig.10). It is the greatest determining factor in dense graded pavement performance .For small areas; loaders, backhoes, skid steers, excavators, or hand placement may be most perfect. Each lift is typically watered to achieve its optimum moisture content then compacted based on the maximum dry-density of the material, which is usually between 90-100% of maximum compaction available. For driveways, parking lots, and other light load

applications, 92-96% compaction is commonly considered sufficient. In roads and high-load vehicle application, 97-100% possible compaction is common. It's important not to compact or pave on an overly saturated or 'spongy' subgrade as not only can rutting occur during material placement, but a spongy or 'segregated' subgrade under aggregate base is not conducive to a long term durable pavement section.
The methodology to solve the problem is based on the incorporation of geo-synthetic reinforcements into AASHTO (1993) design. The method considers the pavement as a multi-layer elastic system having an overall structural number (SN), Various laboratory tests were performed as per Indian Standard Specifications to determine the geotextile strength for various condition ;
1. Tensile strength.
2. Puncture strength.
3. Tear strength.
4. Burst strength.
Above test give the following main function in the geotextile road pavement.

SL.NO.	Name of Geo-textile Equipment	Applications
1	Cross Permeability Test Apparatus	For measuring normal permeability known as permittivity
2	Cone Drop Test Apparatus	To determine the tear strength of Geotextile materials
3	Dry Sieve Test Apparatus	For relative comparison amongst the geotextiles
4	Geotextile Permeameter	For meeting the test requirements of water permeability of Geotextile
5	Gradient Ratio Test Apparatus	For direct measuring of geotextile clogging potential
6	Hydrodynamic Sieve Test Apparatus	For determining the porometry of the geotextile being investigated
7	In-Plane Permeability Test Apparatus	Useful for drainage applications
8	Interface Friction Measurement Apparatus	To evaluate both 'frictional' as well as 'pull out resistance' of soil reinforcing materials at a shear rate and drainage condition as desired by the designer
9	Large Pull Out Test Apparatus for Geo Synthetics	To measure the interface friction between GI Strips /Geosynthetics and Soil.
10	Long Term Flow Test Apparatus	For determining the long term flow capability of a geotextile.
11	Thickness Gauge	For measuring the thickness of the geo-synthetics/ reinforcing material with an accuracy of 0.001 mm for thickness up to 25 mm.

Table 1. Name of geotextile equipments and its application

3.6 Maintenance Considerations:
Regular inspections should be made to determine if cracks, tears, or breaches have formed in the fabric; if so, it should be repaired or replaced immediately. It is necessary to maintain contact between the ground and the geotextile at all times. Trapped sediment should be removed after each storm event.
3.7 Limitations:
1. Geotextiles (primarily synthetic types) have the potential disadvantage of being sensitive to light and must be protected prior to installation.
2. Some geotextiles might promote increased runoff and might blow away if not firmly anchored.
3. Depending on the type of material used, geotextiles might need to be disposed of in a landfill, making them less desirable than vegetative stabilization.
4. If the fabric is not properly selected, designed, or installed, the effectiveness may be reduced drastically.
However all the above limitations can be overcome if proper care is taken in selecting the type of geotextile, method of installation and finally proper maintenance after installation.

4. CONCLUSION

Geotextiles performance and effectiveness depends upon the strength of the fabric and proper installation. Geotextiles are a cost effective way to insure better drainage & stabilization of sub grades. Hence it can be concluded that use of geotextile in road construction is very effective only if proper handle with care is taken.
In poor soils the soil sub-grade strength and other desirable properties can be achieved by various means. The conventional method such as lime, cement, fly ash stabilization can be used as per their availability and practicality. The geo-synthetics offers wide variety of products to solve may geotechnical problems being non-biodegrable and costly. Their use should be restricted the natural materials like coir and jute geotextile can be an option to improve the poor sub-grade soil. The laboratory and field studies have been done on the application of jute and coir geotextile in road construction in poor marine place. So successful application of it, at places where Black Cotton soil which viz. expensive in nature, low shear strength, high compressibility, swelling and shrinkage, on embankment of road.
Textiles are not only clothing the human body but also our mother land in order to protect her. Extensive awareness should be created among the people about the application of geotextiles. Geotextiles are effective tools in the hands of the civil engineer that

have proved to solve a myriad of geotechnical problems. By reducing fiber diameter down to the nano scale, an enormous increase in specific surface area to the level of 1000 m2/g is possible. This reduction in dimension and increase in surface area greatly affects the chemical/biological reactivity and electro activity of polymeric fibers. Because of the extreme fineness of the fibers, there is an overall impact on the geometric and thus the performance properties of the fabric. There is an explosive growth in worldwide research efforts recognizing the potential nano effect that will be created when fibers are reduced to nano scale.

A granular base thickness increase resulted in an increase in cost-effectiveness in both design methods. However, a greater increase in base thickness obtained a smaller percentage increase in cost-effectiveness.

Structure number was thought to be a common parameter to characterize the strength of pavement. However, during the sensitivity analysis, this feature does not show a regular pattern in the cost-effectiveness ratio among the different structure numbers for both design methods. Sub-grade strength is an important feature in the performance model. When Perkins' design method was used, the stronger the sub-grade, the smaller the cost effectiveness ratio was gained. A similar pattern was found when Al-Qadi's design method was used. However, there was a difference between these two design methods.

Although the benefit decreased when the strength of the sub-grade increased, overall, Al- Qadi's design method still showed improvement in cost effective value. By contrast, Perkins' design method suggests that with an increase of sub-grade strength from CBR=0.5% to 6%, the cost-effectiveness ratio would decrease. Geotextiles are a cost effective way to insure better drainage & stabilization of sub grades. Hence it can be concluded that use of geotextile in road construction is very effective if proper care is taken and is a material which is here to stay.

5. AKNOWLEDGEMENT

I take this opportunity to express my cordial gratitude and deep sense of indebtedness to Assistant Prof. Satish Parihar and Assistant Prof. Vikalp Saxena for the valuable guidance and inspiration throughout the Work. . I express my gratitude and thanks to all the staff members of Civil engineering department for their sincere cooperation in furnishing relevant information to complete this Project well in time successfully. I extend a special word to my friends, who have been a constant source of inspiration throughout my Project work.

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