Chapter – 1

Introduction and Background

1.1 Introduction

The International Fund for Agricultural Development (IFAD) has been providing assistance to the Government of Bangladesh to implement the Community Based Resource Management Project (CBRMP)-LGED in the district of Sunamganj for nine Upazilas. The project implemented period is 12 years, from January 2003 to June 2014. Total budget is US$ 29.27 million, with a loan of US$ 24.94 million from IFAD, a contribution of US$ 3.69 million from the Government of Bangladesh, a US$ 0.64 million by the community/beneficiaries in labor, kind and cash.

The objectives of the project are to: (i) increase the assets and income of 90,000 households by developing self-managing grass-roots organizations to improve beneficiary access to primary resources, employment, self-employment and credit; and (ii) support the development of a viable national institution to replicate the project approach in other areas of Bangladesh. The project's objectives will be met through the financing of five components designed to assist the poor: (i) labor-intensive infrastructure development; (ii) fisheries development; (iii) crop and livestock production; (iv) credit and (v) institutional support.

The infrastructure component of the Sunamganj Community-Based Resource Management Project (CBRMP) has focused on building village roads to connect communities with the main road network. Local community roads have often been overlooked, impacting adversely on the livelihoods of village communities. In Sunamganj, roads are undeveloped partly because of the seasonal flooding in most of the district. Lack of roads prevents people from bringing their produce to market, children from attending school, people from getting to hospital and often farmers from bringing harvested crops home.

Roads built by the project are concrete roads rather than bituminous pavements. The project is now supporting the construction of two types of concrete roads RCC and Concrete Block (CB) of 2.6 m and 2 m wide. The project supports the participation of the community in selecting, planning, monitoring and maintaining the RCC roads. Although the roads are built by local contractors, the community is involved in planning the program of work, monitoring the construction and ensuring maintenance. This work is organized through an Infrastructure Management Committee (IMC). The committee is drawn from community organizations established by the project. It comprises seven to nine members, of whom at least two are women.

In case of CB roads instead of employing contractors, local communities acting as Labor Contracting Societies (LCS) are undertaking the construction. Block making can be done in advance of laying the road, allowing group members, especially women, to fit this work in with other household tasks.

Construction through LCS increases community involvement and generates a significant amount of employment, including for women who make many of the blocks. Significant skills are also developed. Block making takes place in the September to November during slack period when little other work is available.

At this stage the Project as well as IFAD wants to understand the technical viability of the roads to plan more effective approach in future. Accordingly Mr. Sk. Md. Mohsin, the Project Director CBRMP - LGED issued a Letter of Invitation and the RFP [Appendix-A] to the Bureau of Research Testing and Consultation (BRTC) of Bangladesh University and Technology (BUET) to do the study work.

1.2 Objectives of the Study

The study has been initiated to understand the impact of the block road, its performance and to suggest improving the design for its better performance and sustainability. Accordingly the following impact and performance assessment studies have been identified to carry out.

- Performance study
- Socio-economic impact assessment study
- 3D Finite Element analysis of the pavement system
- Road safety study

These studies have been carried out taking into consideration the technical viability of the construction of block road as well as its social impact. The technical viability includes the ability of the road to serve the community with satisfaction, its relative efficiency and sustainability aspects.

Chapter – 2

Scope and Methodology of the Study Proposed

2.1 Study Team and the Approach

The study was conducted by the Bureau of Research Testing and Consultation (BRTC) of Bangladesh University of Engineering Department (BUET) with a team comprising Professor Md. Shamsul Hoque PhD (Team Leader and Transportation Expert), Professor Alamgir M. Hoque PhD (Advisor), Professor Md. Saiful Alam Siddiquee PhD (Geotechnical Expert and Pavement Modeler), Associate Professor Md. Mizanur Rahman PhD (Concrete Technology Expert), Assistant Professor Zia Wadud PhD (Applied Econometric Modeling Expert) and Assistant Professor Charisma F. Choudhury PhD (Transport & Survey specialist).

The study team visited the project area namely Sullah, Derai and South Sunamganj from October 21 to 23 2009 and Sunamganj, Tahirpur, Jamalganj, Bishwambharpur and Derai from May 18 to 20 2010 to undertake questionnaire survey as well as to discussed with different cross section of the people including the road users, LCS members constructed the roads, farmers, traders, road maintenance workers, project staffs involved in road building and the LGED engineers including Executive Engineer of Sunamganj. Besides, the team exclusively discussed with the project director of CBRMP on different issues on block road and the future scope of this kind of pavement. During the field visits the consultants objectively collected information for assessment of block pavement as well as subgrade layer, CC block and soil samples are also collected from the study area for laboratory investigation. Side by side non-destructive Schmidt hammer tests are performed to determine in-situ strength of the paving blocks.

2.2 Data Collection

The data and information that were collected to perform overall assessment of the LCS based block pavement roads are presented bellow :

To evaluate performance of pavements

- Observed block and rigid pavement roads with different ages, types and loading conditions
- Observed mode of distresses and damage patterns
- Obtained information regarding pavement stability after receding of submerged water; pavement's edge confinement condition; condition at the interface of pavement and cross drainage structures etc.
- Conducted condition survey of blocks by using in-situ Schmidt Hammer typed non-destructive test (NDT)
- Blocks were collected from different sites for laboratory investigation viz. to know size, shape, weight, uniformity/finishing and block strength
- Observed joint conditions
- Collected maintenance record of block and rigid pavements

To assess riding quality and roadway safety

- Measured the amount of differential settlement per unit length
- Studied user perception regarding discomfort of
    - passengers due to jolting of rickshaw and hitting head with the hood
    - non-motorized pullers to carry heavy freight
- Carried out road users' accident risk perception study
- Measured speed of motor cycles

To assess mix design of concrete

- Collected details of concrete mix design (ingredient types , mix proportion; water-cement (w/c) ratio; method of mixing; curing; form works
- Captured whole process of concrete mixing and block making process by video
- Collected ingredients for laboratory investigations

To perform socio-economic impact study

- Undertaken questionnaire survey among different cross section of the people

To assess design aspects of pavement

- Collected information regarding different steps and sequence of activities
    - Layer system
    - Timing of block constructions, subgrade preparation and block laying operation
    - Total time of construction

- Collected information regarding geometric design of pavement
    - Crest width, pavement width
    - Type of vehicles plying on the road
    - Design vehicle
    - Speed of traffic stream

- Collected information regarding structural design of pavement
    - Subgrade condition (collected soil samples from different sites for laboratory investigations viz. to know density/CBR/bearing capacity of saturated subgrade)
    - Maximum axle load of vehicle
    - Design strength of concrete
    - Climatic/Environmental loading condition
    - Duration of submerged condition
    - Average height of submergence
    - Embankment height (if any);
    - Cross drainage structures

Chapter – 3

Field Observations on Block Pavement Roads

3.1 Introduction

Sunamganj haor basin is primarily a low land and a deep flooding zone. The area is too backward in road communication. Maximum areas face inundation during monsoon for six to seven months over the year. Road building is a difficult task considering the availability of contractors, mobilizing materials, getting sufficient favorable time for construction work and so on.

Considering all those difficulties, LCS based block road construction system has been introduced by Engr. Sk. Md. Mohsin Project Director, Community Based Resource Management Project (CBRMP) of LGED. With this LCS system, roads are now being constructed by the local people from locally available materials. Stage construction also allows the work to be carried out during favorable time to the local people. The most positive part of constructing labor intensive block pavement is that it creates employment for a longer period of time during the slack period particularly for the poor community in Sunamganj. This type of initiative is first of its kind in Bangladesh and holds good prospect. In this Chapter the LCS based block road construction system is scrutinized critically and assessment is made based on the field observations as well as undertaking condition survey of the existing roads.

3.2 General Observations

3.2.1 Steps Involved in Block Based Road

Field observations revealed that construction of block pavement road involved the following steps

- Preparation of ground by cleaning and grubbing
- Removing soil by cutting of 8 to10 inch deep box
- Compacting subgrade manually by hammering action
- Placing and compaction of 3 inch sand cushion layer at saturated surface dry (SSD) condition
- Placing of 0.8mm thick polythene sheet
- Inserting edge blocks
- Laying cement concrete blocks row wise
- Making joints around the blocks using mortar

3.2.2 Construction Period

It is gathered that in haor areas, road has to construct between December and April and even this time is often shorten either by late receding of water or early flush flood. For better performance of road, ideally construction should be made on dry subgrade, but it is learned that due to time constraint the road construction has to start immediately after receding of water and virtually on saturated subgrade. This obviously affects the desired level of densification in compacting subgrade. Moreover, as by and large the roads under the study area are being constructed with very tight right of way (2.0m-2.6 m), conventional roller cannot be used for subgrade compaction. That is why, any kind of high quality road viz. flexible or rigid pavement would not be suitable to construct with this type of narrow right of way and poor support condition.

3.2.3 Ingredients

During field visit it was observed that though design strength of cement concrete is 18 MPa (2500 psi), in general high quality ingredients like stone chips and Sylhet sand, as can be seen from the following photographs, are being used in the construction of cement concrete based block pavement road, which are not necessary at all for such a low strength concrete. Field survey revealed that in most parts of the project area, stone chips and sands are not easily and readily available. Due to unavailability of these materials as well as lack of continuous roadway infrastructure, ingredients need be transported to the road construction sites from faraway often by using different modes of transport; first by truck then by boat and finally by rickshaw van and thereby incurring higher transportation cost.

Considering the scarcity of stone chips and Sylhet sand and most importantly requirement of concrete strength is not so high, gravel or shingle and local sand can easily be used. Good thing with the use of gravel or shingle is that due to round shape it improves workability of concrete mix by a significant margin which is very important in ensuring quality of concrete. In the field it is observed that during mix preparation among the LCS members there is an inherent tendency to increase the amount of water for improving workability and thereby to make concrete mix working friendly. But increase of water-cement ratio has significant bearing on both strength and durability of concrete blocks. As such, use of graded round gravels, which has the potential to improve workability of concrete mix, in place of crushed angular stone chips, would be an effective as well as self enforcing measure in maintaining quality of concrete blocks.

Moreover, thousands of compressive strength test results on concrete cylinders those were made of various types of brick chips and mix proportion and sent to the Concrete Laboratory of BUET for testing by different clients revealed that with brick chips 15-20 MPa strength of concrete can easily be achieved. As such, considering the facts that stones chips or gravels both are needed to bought and transported to the remote site as well as considering the low strength requirement of CC blocks i.e. only 18 MPa, locally available brick chips can be used as an alternative of stones or gravel to reduce the cost of production keeping all other benefits of the existing concrete block technology. Particularly, advent of green bricks with low carbon footprint would not only make the block pavement road cheaper but also environmental friendly. It is obvious though durability of concrete with brick chips would be lower than that of concrete with stones but considering the temporary nature of block pavement road, the artificial aggregate made of brick could be a good alternative. Particularly for the coastal areas of Bangladesh where roadway facility is difficult to provide not only due to scarcity of stone but also daily submergence problem caused by the influence of tidal flow.

3.2.4 Concrete Mix Preparation and Block Making Operation

During the field visits close observation of concrete mix preparation and block making operation revealed that :

- Bringing and mixing ingredients are not women friendly works. Particularly making cater at the center of ingredients heap, handling 50kg cement bag, carrying bucket full of water and mixing all the ingredients homogeneously which need lots of physical labor. That is why it was observed that though women are given the job to do but eventually they give it sub-contract to other male group to get the job done for them. Thereby, quality of work may be sacrificed particularly if it is not done by trained and qualified contractors. Moreover, quality may further be sacrificed due to subcontracting system, where profit is shared by another group which is not considered in the engineer's estimate. It is learned that outsourcing of mixing, casting and laying operation costs around additional Tk. 11/= per block. Following snapshots are taken to demonstrate the concrete mix preparation and block making operation in the field.




- In the field, women were found to be involved in those activities particularly which demands less physical labor viz. carrying aggregates, concrete mixtures, finished blocks and preparing subgrade etc.

- Though in concrete mixing, water-cement ratio is a very important issue and need to be conformed accurately but in reality it was found to be not observed as properly as it should have been. It was observed that pond water was being poured in the mix by using a graduation less container and virtually without any measurement and control. It was also found that among the field workers there is a tendency to use high amount of water in the mix with a view to improve workability and thereby to make it easier for women to handle and carry heap less concrete. Moreover, to get the benefit of self compacting fluid concrete in making block without any temping effort.

- It was observed that where there was shortage of CC block mould, workers took out semi-solid block sample from the mould even within 30 minutes of casting and thereby causing disfigured and irregular shape of blocks. In this regard, use of relatively quick setting cement could be a plausible solution.

- Though, to ensure the quality of block making works involving ordinary community people particularly women demands close and continuous monitoring and field supervision, it is learned that by and large road building activities are going on without any proper supervision due to acute shortage of manpower and lack of responsible supervisor and most importantly due to scattered nature of work places over a vast area.

- After casting, the blocks are assembled on the untreated surface of the soil. Here there is a scope of improvement. The surface can be treated with low cement content or lime or any other similar material to keep the material in place while inundated in rainy season. Aggregate blanket may be used underneath the blocks to enhance the drainage so that it reduces the material erosion in case of inundation and keeping the surface flat for a long time.

- It was also observed that due to scarcity of highland in the study area, prepared bocks are kept in stack with high height which in turn affects uniform level of curing, particularly when it is done with less amount of water. This curing related problem can be addressed by using a special admixture which has the potential to make curing less concrete.

Considering the fact that the labor intensive LCS based infrastructure development project is sensitive to quality control and observing the lack of supervision in mixing ingredients, making blocks and curing work, it is essentially suggests that job center based (JCB) concrete block manufacturing system could be a better option.

3.2.5 Block Pavement vs. Rigid Pavement

During field visits it was observed that in general the block pavement based roads are performing better as compared to the rigid pavement roads, particularly when these are built on narrow right of way. In the field, side confinement measure of block pavement is found to be acting nicely to protect subgrade material; whereas due to tight right of way it is difficult to provide shoulder or lateral support to the subgrade of rigid pavement and that is why often rigid pavement is found to be unsupported due to loss of subgrade material. At few locations, the rigid pavements were found to be unsupported due to absence of side confinement and loss/erosion of subsurface foundation material by wave action of water. It was also seen that due to difficulties in maintenance works at subsurface level as well as it is contractor dependent work, the damaged part remain unattended. Another problem associated with the rigid pavement is that after construction without damaging the structure it is not possible to lay any condition responsive cross drain pipe or channel at subsurface level for which the need may arise later on.


Unsupported Rigid Pavement


Damaged Rigid Pavement

Since the causeway type block pavement road is usually build without embankment, thereby there is no need to construct equipment and skilled manpower dependent cross drainage structures viz. bridge/culvert. As such, the block pavement roadway system can easily be outsourced to the community level. In contrast problem associated with the RCC rigid pavement is that both construction and maintenance works are contractor dependent, as it requires special skilled labor and equipment. That is why the rigid pavement is difficult to be built by involving ordinary community people like woman.

Usually fit and forget typed rigid pavement is meant for heavily loaded traffic and appropriate where maintenance requirement is minimum but in the study area it is observed that the impact of climatic load is more pronounced than that of traffic load. This special loading pattern implies that even flexible pavement would not be a good alternative. Periodic submergence characteristics of the area essentially suggests that road type has to be weather resistant as well as easily be maintainable. As such, adoption of semi-rigid typed block pavement based road is found to be the most appropriate and condition responsive.

3.2.6 Block Pavement vs. Herring Bone Brick (HBB)

Attempts have also been made to explore the potential of Herring Bone Brick (HBB) roads as an alternative of block pavement. However, literature review shows that though conventional HBB is a low cost, easily maintainable road and community involvement is possible in construction and maintenance works, it has got the following shortcomings:

- Due to the small foot print of building block (brick)
  - HBB road is prone to settlement, particularly with soaked or saturated subgrade conditions
  - Punching and pumping problems are common with wet subgrade, particularly for dynamic traffic loading conditions
  - Stability of HBB road structure largely depends on support conditions; in general it performs better if it is built on well compacted dry subgrade with uniform support condition and for low level of traffic loading

- Performance of HBB road is very sensitive to the firmness of edge confinements which is very difficult to ensure for the road with tight right of way

- Due to thin shape of brick as well as its brittleness, HBB road is
  - Weak in impact loading particularly those induced by dynamic traffic stream
  - Prone to fatigue failure

- Limited scope of involving women in HBB road particularly in brick production

- Non-uniform riding quality of HBB road increases passenger discomfort, transport cost and vehicle depreciation

- Due to light weight, brick is more prone to washout by the current of flush flood water

- As brick has good use in different civil works, it has got a high opportunity cost and thereby associated with theft problem

- Due to less durable and high settlement potential of HBB road, it requires frequent maintenance work

- Relatively short life cycle and has little scope of reusing bricks

- Basically, HBB road is mainly suitable for building
  - Walkway
  - Road with low level of traffic
  - Road with dry subgrade or formation on embankment without capillary rise potential

Taking the above issues in cognizance as well as considering the inherent periodic submergence and traffic loading conditions, it appears that HBB type pavement system would not be an improvement over the submersible concrete block pavements in the haor areas.

3.2.7 Other Important Observations

It was observed that this causeway or submersible typed temporary block paved roads (Dobo rasta) are acting as a bridge among the disconnected areas and thereby providing development touch to the marginalized people where there is no formal RHD and LGED roads. It was also observed that this LCS based infrastructure development approach is empowering woman and marginalized unskilled poor farmers. Moreover, this temporary nature of block pavement road could be considered as the precursor of high type pavement. If needed cement concrete blocks can be reused to build other temporary access or side roads and to protect side slope of embankment.

Field observation and measurement showed that though the mortar joints were performing fine but at few occasions it was found to be in damaged condition due to differential settlement of adjacent blocks. Moreover, it was observed that due to poor workmanship of mortar work causing riding problems. It is to be noted that good riding quality of road is an important issue for the community people.

During the field visits it was also found that after receding of water, people often cannot use the causeway type block pavement road due to lack of continuity caused by submergence of small portion of the road particularly that is built at the depressed ground. As a result, road segments with relatively low ground delayed the usage of the road for a considerable period of time. After receding of water to make the road functional as earlier as possible it would be better if the road segment at low level can be built on the embankment with proper cross drainage facilities.

It has revealed that this community based labor intensive infrastructure development approach has the potential to create strong sense of belongingness and ownership of the infrastructure among the community people. Whoever becomes involved with the road building activities naturally they as well as their children feel proud of thinking that the roadway facility has been built by their direct participation and contribution. As a result they always try to keep the road operational by maintaining it.

Filed observation revealed that LCS based roads are found to be most appropriate where:

- Construction of embankment based road is not feasible due to biodiversity and fragile ecological setting of the area
- There is no scope or no need to construct good quality of road and stage development strategy would be the most appropriate approach
- Due to economic constraints; construction of high type road is not feasible
- There is a need to create employment opportunity at community level particularly during the slack period

During the field visits while talking with the villagers it appears that in general they rate the LCS based roadway building approach is very good and wherever the Consultants have visited it was found that there was a strong desire to have more of this type of roadway facility.

3.2.8 Advantages and Disadvantages of Block Pavements

Based on this study work it is found that the block pavement system has many advantages to offer considering the local context as well as some disadvantages were also observed from technical and social points of view. In the following sections these have briefly been highlighted. The major advantages of block road are :

Considering the technical aspects:

- It is not so susceptible to flood;
- There is scope to reuse the block;
- It is feasible to use in stage development towards building permanent road in that area in future;
- The pavement is adaptive to nature;
- Construction process is simple and community can do it instead of contractors – who usually lack honesty and integrity in work;
- No need to construct high embankment;
- Block based submersible causeway is well suited for the eco-sensitive area and
- Block road is easily maintainable

Considering the social aspects:

- Highly labor intensive, thereby create the scope of employment for the poor;
- Communities can participate directly instead of through the middle man/ subcontracting;
- A good source of income for the poor, particularly for the destitute women;
- Offers employment opportunity during the slack period;
- It develops the skill of the poor for better employment and the scope to work in construction other than the project activities;
- It creates social capital among the poor community;
- It develops the feeling of ownership in the community and
- Block road is highly in line with project objective to create scope for the poor to reduce poverty.

Most importantly, the LCS based low cost block pavement road is helping in making the mechanized method of cultivation popular among the farmers by providing access to the beel based agricultural field and allowing mechanized plough machine, paddy separator directly to enter in to the paddy field and tractor/rickshaw van to transport crops to the market without any need for storage. From the villagers point of view it is very important since there is an acute shortage of high land and also it is adding more value to their products. Moreover, the mechanized method of cultivation is helping not only in reducing the labor shortage related problem that arises particularly during the harvesting period but also reducing harvesting and crop processing time significantly.

Another important aspect of block pavement is that the adaption potential with rising water level due to climatic change. With Bangladesh facing the major brunt of the climate change related adverse impacts, the coastal zones in the country are at a severe risk to sea level rise and inundation. The frequency and magnitude of other natural hazards such as cyclones and associated inundation of coastal zones as well as flooding of further inland are also likely to increase. Under such circumstances, the submersible concrete block pavements can offer a viable adaptation measure by allowing the water to flow unhindered. This would encourage quicker retreat of cyclone and flood water. Such roads can also be applicable to other countries facing the risk of climate related inundation due to natural disasters.

The following are the major disadvantages or weaknesses of the block based road:

- Due to differential settlement, the riding quality of block road is relatively poor;
- Blocks need uniform support for even surface but it is too difficult to ensure;
- The poor riding quality impacts on higher transportation cost and increase the maintenance cost of transports as well, particularly for the manual vehicles;
- Curing is a problem during winter time due to unavailability of water near to working site;
- Block roads are not carefree or fit and forgets type of structure, therefore it requires regular maintenance. However the maintenance is quite simple; and
- Contractors do not like it as it requires more labors and relatively more time than RCC road; therefore, contracting scheme to contractor is not easy.

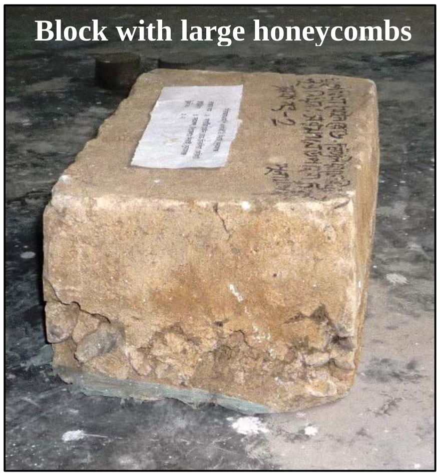
3.3 NDT and DT Tests of Blocks

In order to assess the quality of concrete blocks, both in-situ non-destructive (NDT) and laboratory destructive tests (DT) were performed on six block roads of Sunamganj district namely Chitlia, Shahebnagar, Moinpur, Gahtia Main Road-Chitlia Fery Ghat, Halua Ghat-Moinpur Road and Vayserpar East Shahebnagar. Soil samples were also collected from the subgrade level of these roads for geotechnical investigation and results are presented in Chapter 4. Detail results of NDT and DT are presented in Appendix-B.

In this study non-destructive rebound hammer tests were conducted for assessment of in-situ strength of concrete blocks. Following photographs are taken to demonstrate the NDT test.

From the test results, average compressive strength of the blocks was found to be 2140 psi or 14.75 MPa with average mean error of 646 psi or 4.45 MPa. The observed strength is not up to the level which it should have been. Considering this lower strength of concrete particularly when it was made with rich ingredients viz. stone chips and Sylhet sand, without casting any aspersion it can be said that there is a problem with the preparation of concrete mix. During the field visits, observation on mix preparation revealed that workers involved in preparation of concrete mix have lack of skill in doing the job properly. In our opinion, with the same ingredients 20-25 MPa concrete can easily be achieved if only water-cement ratio is maintained correctly in the mix. It is to be noted here that improper water-cement ratio not only reduce the concrete strength significantly but also affect durability of the blocks.

From the following photographs it can be seen that due to use of excessive water in the mix, segregation of cement paste occurred and resulted blocks with large honeycombs.


Block with large honeycombs


Block with large honeycombs

Since non-destructive rebound hammer test provides only indicative compressive strength of hard concrete, in order to get actual strength of the concrete blocks, samples were collected from the field for destructive test. In the concrete laboratory, 2 inch diameter cylinder specimens were taken from the block samples by using core cutting machine. Snapshots of core cutting machine and core samples can be seen from the following photographs.


Core cutting operation


Core Specimens

From the compressive strength test of 12 core specimens, average strength of concrete blocks is found to be only 720 psi or 5.96 MPa, which is well below 18 MPa design strength. Most importantly it was observed that for all 12 core specimens the mode of failure was ‘mortar’, which definitely suggests that cement as a binding material could not impart properly in gaining intended strength of the concrete. It might be due to either use of less amount of cement or use of improper water-cement ratio or segregation of cement paste from the concrete mixture. During core cutting it was observed that in every block there were lots of honeycomb and aggregate gradation was also appeared to be poor. In the concrete mixture there were lots of larger sized aggregates. All these revelations indicate that there is something wrong with the preparation of concrete mix, which needs to be addressed very carefully otherwise block based road would not last long.

3.4 Stability of Block Roads

Field survey revealed that among all the visited block pavement roads, most of them were found to be in good shape even which have been constructed in 3-4 years ago. It is to be noted that in the study area roads have to withstand the affect of periodic submergence, battering caused by wave as well as action of running water. The following snapshots are showing the affect of climatic load on the block roads.

During the field survey it was observed that submergence of water did not affect the structure of the block pavement road significantly. Though at few locations, particularly road segment at low level found to be damaged structurally but due to side confinement elements as well as self weight of the cement blocks, the flow of flood water could not wash away the building blocks. The following Photographs are presented to demonstrate the fact. It can be seen from the photographs that the damaged part of the road can easily be made usable by routine maintenance. This essentially suggests that the block pavement has the potential to serve the community sustainably withstanding the forces of natural. As the stability of block pavements largely depends on the lateral confinement, extra care should be taken while placing the side blocks of the road structure.

3.5 Cost Comparison

Cost comparison among various types of roadway systems viz. bituminous, reinforced cement concrete (RCC) and CC block road for three different standards (i.e. village, union and upzila) are made based on the necessary information getting from LGED. Detail analysis and relevant drawings are presented in Appendix C. A Summary table is presented below.

Table 3.1 : Cost Comparison among different types of Roadway Systems

Cost of Road	Roadway Types	Bituminous Carpeting Road	RCC Road (Non submerged)	RCC Road (Submerged)	CC Block Road (Non submerged)	CC Block Road (Submerged)
Construction Cost	Village Road	3,241,080	3,581,399	4,508,239	2,808,140	3,368,820
	Union Road	4,570,209	5,237,867	6,164,707	3,648,620	4,209,300
	Upzila Road	5,606,213	6,490,352	7,417,192	4,489,099	5,049,779
Life Cycle Cost	Village Road	19,573,648	10,768,871	-	11,498,769	-
	Union Road	24,773,200	14,945,983	-	15,852,007	-
	Upzila Road	30,082,445	19,776,306	-	26,030,554	-

Note: Life cycle costs are estimated based on standard schedule of rate's item of LGED and considering maintenance cost for 20 yrs. life time with 10% inflation. Detailed analysis can be seen from Appendix C.

From the above table it can be seen that from total construction cost point of view, CC block road is relatively cheaper than both bituminous and RCC roads. Though, for all standards (village, union & upazila) life cycle cost of CC block road is much (13-40%) cheaper than that of bituminous road but it becomes costlier as compared to the RCC road particularly with the improving standard of road. For village and union roads, the cost of block pavement is slightly (6%) higher than that of rigid pavement whereas for upazila road it is nearly 31% higher. Due to lack of information cost comparison under submerged condition could not be made.

Inferring these findings it can be said that RCC road would be more appropriate for upazila road whereas block type pavement system would be suitable for village and union standard roads. A close look of cost figures also reveals that as compared to the bituminous pavement, the CC block based road would be economical even for higher standard upazila road.

3.6 Summary

As a whole, the LCS based block pavement road construction method is found to be more or less sustainable due to the facts that the road system is constructible as well as maintainable by the community common people and most importantly it is upgradable and condition responsive i.e. any subsurface level work like laying of cross drainage structure can be laid later on. However, there are scopes for improvement of the existing block pavement roads, particularly to improve the quality of the block by introducing mixture machine or compressed block manufacturing technique. It is found that there is further scope to improve the riding quality of the block by improving the method of block interlocking system which is explored in Chapter 4.

Chapter – 4

Socio-Economic Study of Block Paved Road

4.1 Introduction

Any improvement in the transportation infrastructure can have large impact on the socio-economic impacts of communities. Roads connecting remote places spur the growth of communities by lowering the transport costs, increasing accessibility and encouraging trade and enhancing mobility. All these can have significant impact on local quality of life. One of the objectives of this study is to understand the socio-economic impact of the rural roads built under the CBRMP. The purpose is also to act as an independent check to the socio-economic survey undertaken by IFAD separately. This chapter presents the detailed description of the survey and discussion on the analysis of the results.

4.2 Description of the Survey

4.2.1 Questionnaire Design

A semi-structures questionnaire was used by the BRTC, BUET consultants. Since one of the objectives was to independently verify the socio-economic survey undertaken by IFAD, the consultants opted to use a similar questionnaire, provided by IFAD's consultants. The original questionnaire was modified and additional questions were asked about travel and transport costs.

The survey questionnaire set out to understand the impact of the newly constructed rural roads (both block and rigid). Several impact variables were chosen and changes of these variables were taken as a measure of the impact of the roads. The impact variables primarily include variables related to ease of access and mobility, travel behavior, and ultimate impact on living standards (Table 4.1). Along with these, information on typical demographic and socio-economic variables (e.g. household size, occupation of household head, number of earners, etc.) was also collected. A sample questionnaire is attached at Appendix-D.

Table 4.1 also describes the individual items of the different impact variable classes. Ease of access is represented by ease of opportunities to employment, accessibility to health services, schools, markets, towns and recreation, and women's mobility. For the first six items, the questions asked were qualitative in nature with five possible answers: a lot better, better, same as before, worse and not applicable. In order to understand women's mobility, number of trips before and after the construction of the roads was collected.

Changes in travel behavior were identified by changes in number of trips by different modes: walking, bicycles, motor cycles, rickshaws and boats. Four levels of qualitative answers were registered: more, same, less and not applicable. Standard of living was indicated by consumption of food, income level, housing, household assets and use of NGO services. Once again all the answers were qualitative, with 5 levels of answers.

Impact of the economy was identified by variables such as changes in transport costs, opening of new businesses, increases in land values and changes in use of microfinance.

Table 4.1: Impact variables on which information was sought

Impact assessment variables	Response type	Response levels
Ease of access and mobility after the road		
Opportunities to employment	Qualitative	5
Access to health services	Qualitative	5
Access to schools	Qualitative	5
Access to markets	Qualitative	5
Access to towns	Qualitative	5
Access to recreation	Qualitative	5
Women's mobility	Quantitative	-
Travel behavior after the road		
Trips by foot	Qualitative	4
Trips by rickshaw	Qualitative	4
Trips by bicycle	Qualitative	4
Trips by motorcycle	Qualitative	4
Trips by boat	Qualitative	4
Standard of living after the road		
Food	Qualitative	5
Income	Qualitative	5
Housing	Qualitative	5
Household assets	Qualitative	5
Use of NGOs	Qualitative	5
Impact on the Economy		
Transport costs	Quantitative	-
Opening of new businesses	Qualitative	2 (yes/no)
Increase in land value	Quantitative	
Use of microfinance after road	Quantitative	2 (yes/no)

4.2.2 Survey Process

Ten surveyors were recruited from among the final year students of BUET. In keeping with the spirit of the CBRMP project, special efforts were made for a gender balance among the surveyors. Among the ten surveyors four were female, for whom this was a unique opportunity. A half-day meeting and workshop with the surveyors was arranged prior to the field survey, in order to train them and acquaint them with the survey questions.

The field survey took place on May 19 and 20, 2010 under the supervision of Dr. Zia Wadud. Interviews were conducted at various locations in five different upazilas where the new roads were built. The upazilas are Sunamganj, Tahirpur, Jamalganj, Bishwambharpur and Derai. Wide geographical coverage was aimed for, since impacts can be different depending on the relative locations of the roads and communities with respect to markets, growth centres and other infrastructures. The surveyed areas and the proportion of samples from each area are presented in Figure 4.1. In choosing the locations, care was taken such that all land types were covered, including (relatively) highlands, lowlands and haors. There was adequate representation from both blocked and rigid pavements as well, so that a comparison can be made among the two.

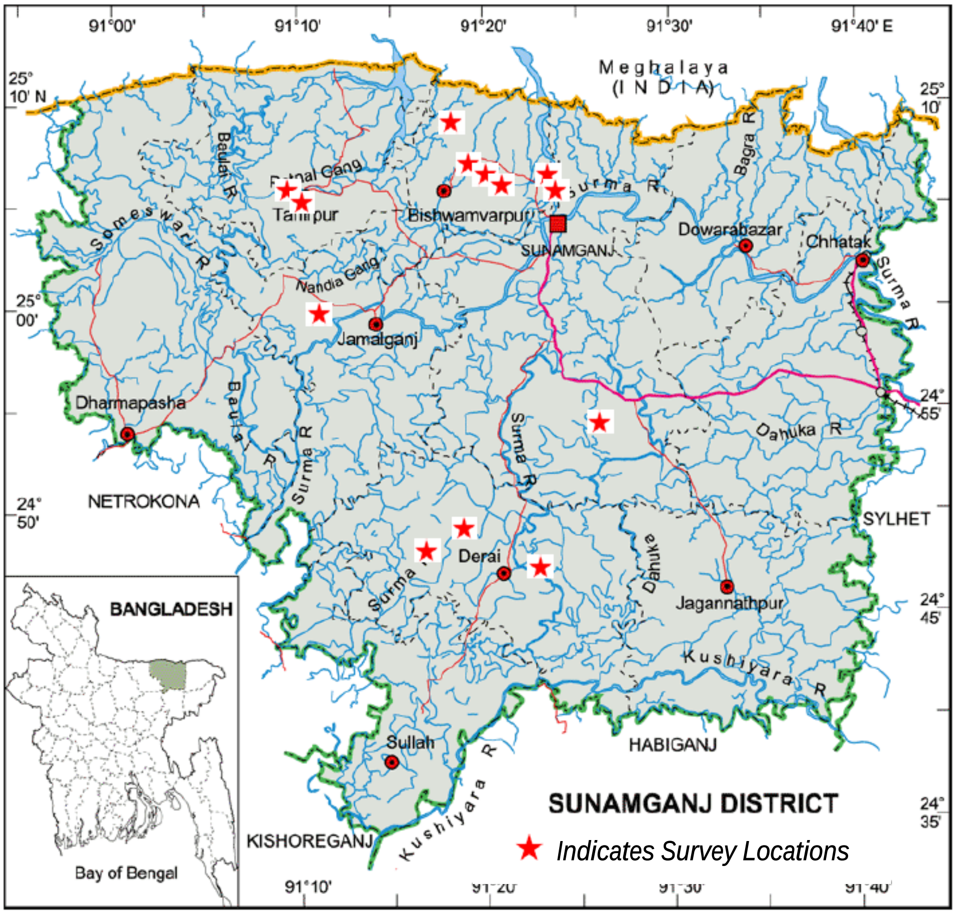


Figure 4.1: Locations of the questionnaire survey

Figure 4.2: Finalizing the survey plan at LGED office, Sunamganj

Initial target was to collect information from 150 random households from the chosen locations. Despite inclement weather (heavy rains) during both the days, the surveyors were able to collect 176 completed (including partial completions) questionnaires. Instead of carrying out a focus group discussion, Dr. Zia Wadud and Dr. Charisma Choudhury exchanged views with the community, often gathered impromptu in small groups at various locations, while the household survey was taking place nearby. This allowed the consultants to have a better understanding of the issues faced by the people relevant to the construction of the new roads. Some of the figures of the constructed roads, the natural setting of the region and surveying process are presented in the report sporadically.

Figure 4.3: Surveying at different locations

Figure 4.4: Conditions were not always favorable for surveying; a submerged road (along the tree line)

4.3 Description of the Sample

Among the 176 households, 43.8% were living near a newly constructed block road, the remaining 56.2% were users of the new rigid pavements. Upazila wise distribution of the sample is presented in Figure 4.5. Although Sadar and Bishwamvarpur are over represented, number of beneficiaries in Sadar upazila is larger than others. Bishwamvarpur is marginally over-represented because of logistics constraints during the survey process. Specific areas and roads surveyed within each upazila are presented in Appendix-E.

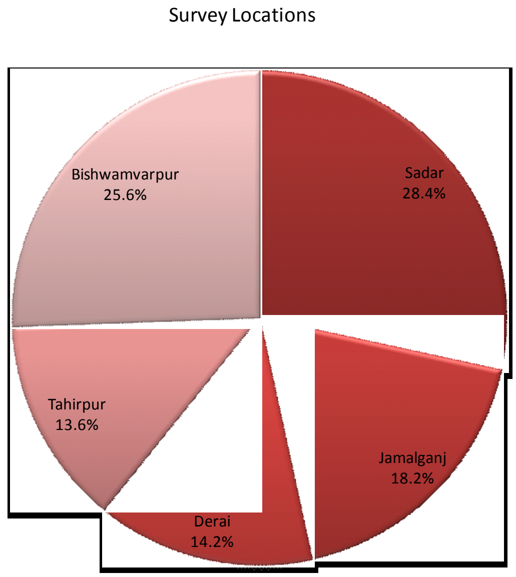


Figure 4.5: Location wise distribution of the sample

Gender distribution among the respondents was more or less equally divided. 92 respondents were male (53.4%), while the rest were female (46.6%). Other relevant demographic characteristics e.g. relationship of the respondent with household head, number of members and earners in the household and occupation of the household head are presented in Figure 4.6. Almost half of the respondents were the heads of the household, while 32% were spouses. 42% of the households had between 4 to 6 members, where 35% had 7 to 9 members. More than 10% of the households were rather large, with more than 10 household members. Majority (60%) of the households had only one earning member, while 27% had 2 members who were earning a livelihood. Agriculture is the primary occupation for majority of the heads of the households (56.3%). Although many household head can have more than one occupation, the chart shows only the primary occupation, as described by the respondents.

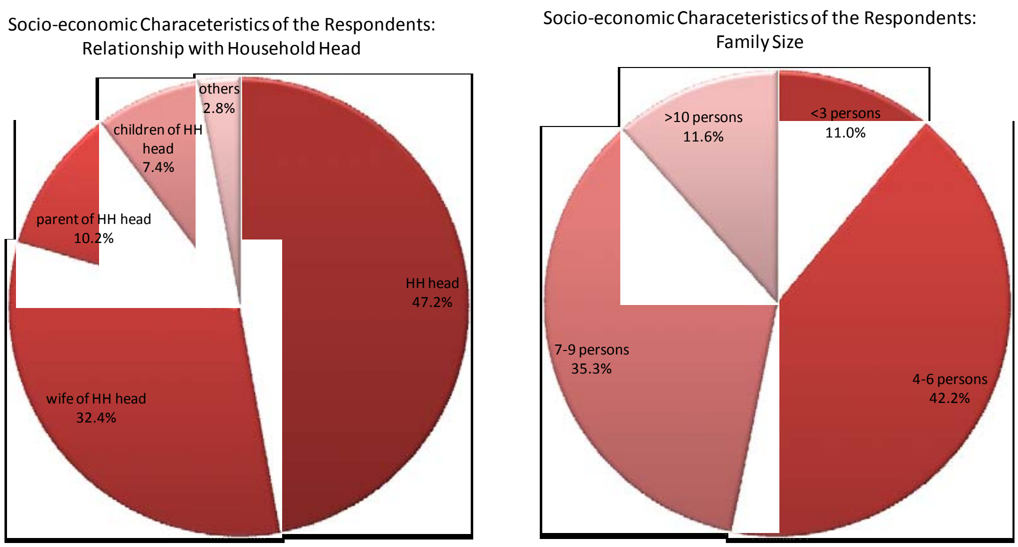
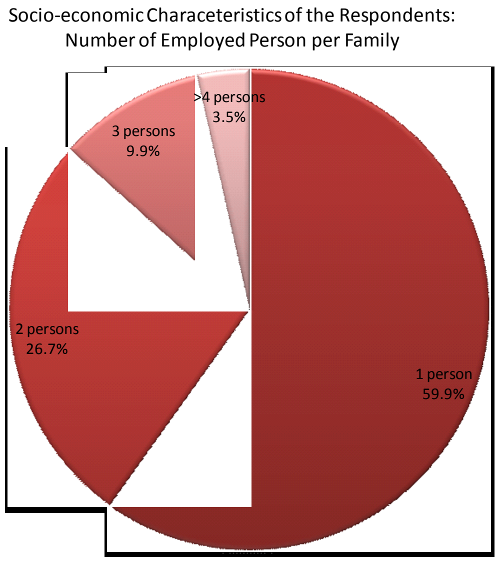


Figure 4.6: Socio-economic characteristics of the respondents and their households



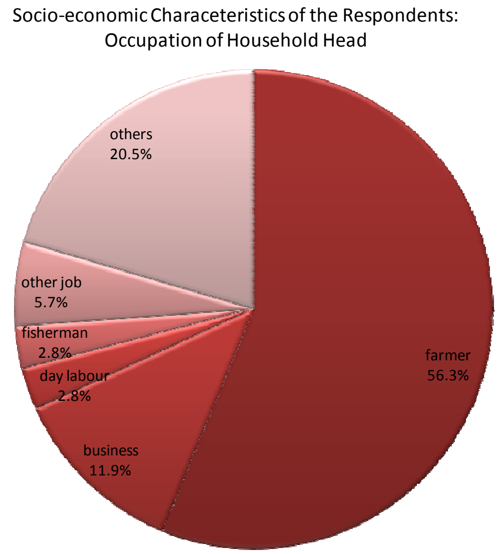


Figure 4.6 (cont.): Socio-economic characteristics of the respondents and their households

4.4 Survey Results

Debriefing sessions with the surveyors indicate that the respondents were often not comfortable answering quantitative questions. Even for such basic questions as income, the respondents had difficulty answering and response rate was poor. One of the possible reasons could be that there were a high number of female respondents, who did not have much knowledge about the income of their spouses. This section presents results for all households combined to start with. Any possible differences between the impacts of block and rigid roads, or households involved with the project vs. those without any involvement are presented afterwards.

4.4.1 All Households

Results for all households indicate that the roads have positive impacts on all our impact variables. Almost all the respondents answer positively on the ease of access and mobility variables. Figure 4.7 presents the proportion of respondents with different responses on the impact of the road on the access and mobility variables. More than three-fourths of the respondents mentioned that the road have increased their opportunities for employment.[1]

An overwhelming 95% of the respondents replied that there was an improvement in their access to health services. Discussions with the respondents indicate that road has enabled the sick to use rickshaws to go to health services. Before the roads, it was difficult for moderately sick people to go to hospitals or health services since transportation was difficult during the dry season and only the severely sick were taken to the hospitals. The roads enabled sick people to seek medical attention at earlier stages of their illness, more conveniently.

A large majority of 87% of the households felt access to school were better due to the new roads. For the rest, the school is either nearby (thus roads do not improve accessibility) or the households do not have school-going children. 95% and 80%

[1] The 1.1% respondents with negative views were two boatmen who lost patronage due to the road

mentioned that access to markets and towns have improved. Especially, 64% of the respondents believed that access to markets vastly improved due to the roads. The smaller positive proportion for access to towns is because a large proportion of women do not go to the town: for them the accessibility remains either the same, or they answer not applicable.

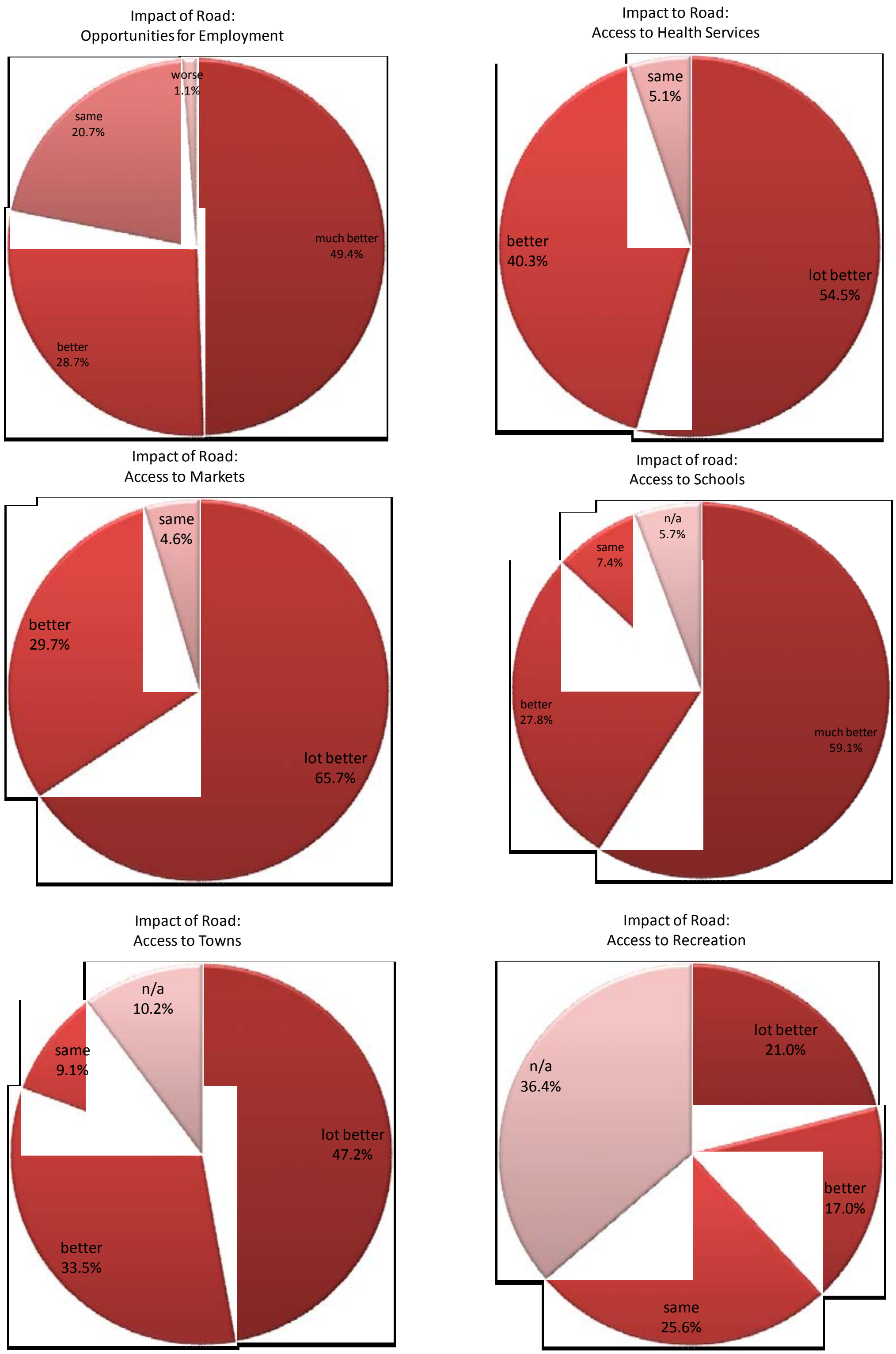


Figure 4.7: Respondents view on the impact of road on access and mobility variables

Only 38% of the respondents said that access to recreation has improved. Note however, a large share of respondents, about 36%, replied that recreations such as visit to cinemas in towns were not applicable for them. Also a large portion of our respondents were female, for whom recreation is more about visiting neighbors, which has not improved largely due to the roads.

Women's mobility was expressed in terms of number of trips to the town before and after the road. The trips are then grouped into four categories. More than 50% of the respondents felt that women's mobility has improved after the roads. A significant proportion, however, still feels that the question does not apply to them because the women to not travel to towns or markets, or did not answer. One answer often mentioned during the discussion with the surveyors is that women can now travel alone because of the new roads.

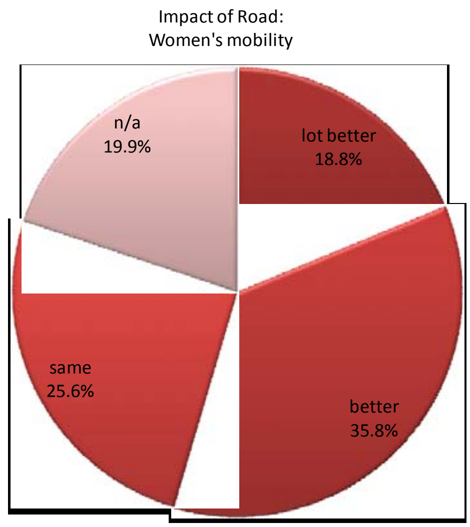


Fig. 4.7 (cont.): Respondents view on the impact of road on access and mobility variables

The second set of impact variables were about travel behavior before and after the road. The response variables have four qualitative answers: more, less, same and not applicable/not answered. Figure 4.8 presents the responses. Almost 60% of the respondents mention that they now travel more by foot. This is possibly an indication of an overall higher number of trips due to better walking conditions on the new roads as compared to the earthen roads before. Around 31% of the respondents indicate fewer walking trips. These households possibly switched to other transport modes which are now made feasible by the new roads (e.g. rickshaws, bicycles, motorcycles).

More bicycle travel was undertaken by almost half of the households. Around one-fourths maintained status-quo with bicycle travel, while 4.5% travelled less by bicycle now. Presumably these 4.5% switched to other travel modes (most possibly motor cycles). Around 60% of the respondents indicate they travel more by motor cycle since the roads have been built. Note that motor cycles work as a para transit (personal transport for hire), and everybody does not have to own a motor cycle to ride a motor cycle. The new roads in fact generated employment through new routes for the motor cycles used as para transits. An overwhelming 93% of the households increased their travel by rickshaw. This is no surprise since rickshaws require a smoother surface than motor cycles or bicycles, and new roads significantly increased the supply of smoother riding surfaces as compared to the earthen roads.

A majority of the respondents uses boats less than before. This is counter-intuitive since the roads are aimed at improving dry weather traveling, whereas boats are wet weather travel modes. One potential explanation is that people can start using the roads even when it is submerged in shallow water, reducing the boats operating season. The 9.7% respondents showing an improvement in boat use are from an area where the new road cuts across a river, increasing river crossings.

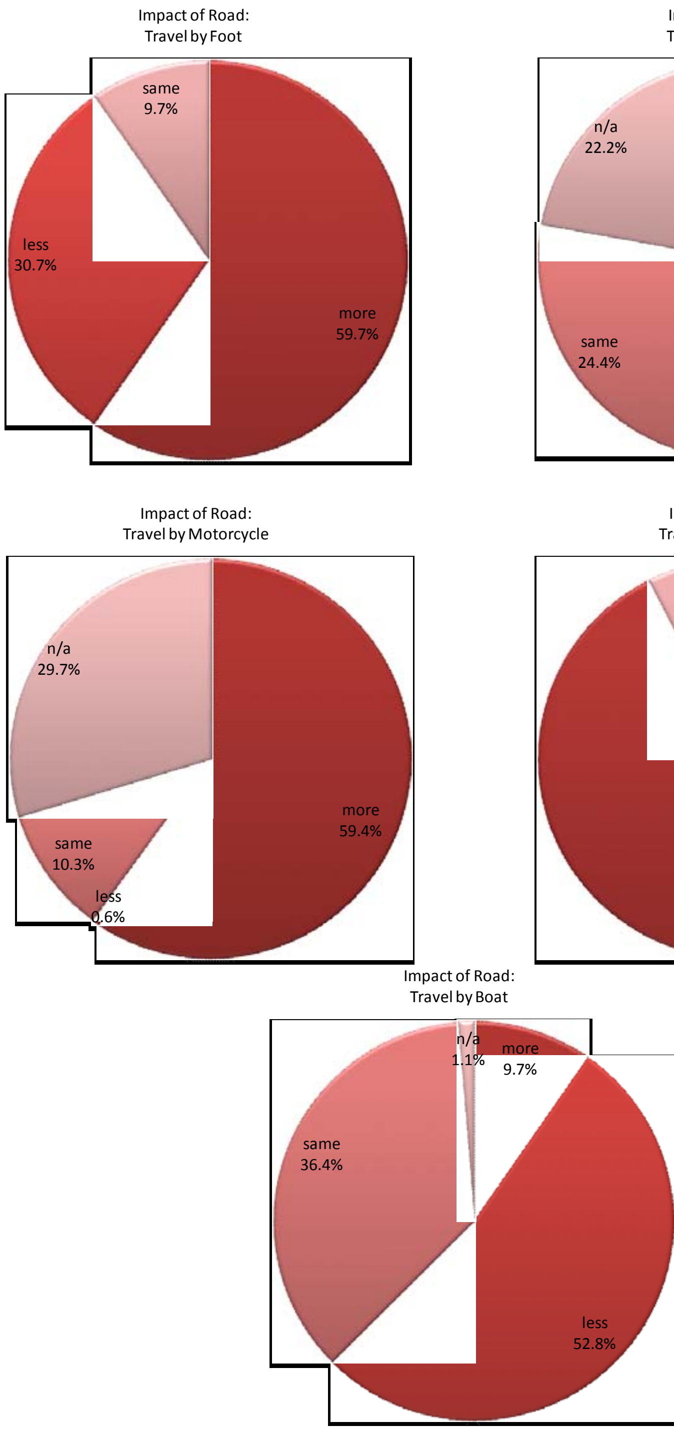


Figure 4.8: Respondents view on the impact of road on travel behavior after the road construction

The third set of impact variables are on standard of living. The respondents commented on their food consumption, income, housing household assets and access to NGO's in this section (Figure 4.9). More than 70% responded that food consumption has improved, of which almost 40% indicated a large improvement. One major comment was that the quality of food improved, since fresh foods are now more accessible and available than before.

Around 75% of the respondents indicated an increase in income since the construction of the road, with 26% mentioning a large improvement. This is expected: new roads reduce travel time, increases accessibility to jobs, ultimately allowing increased income. The new roads also encouraged new road based employment, e.g. motor cycle driving as para transits, pulling rickshaws and road maintenance for destitute women.

Positive responses on the impact on housing and household assets were smaller as compared to other impact variables. Around 43% and 35% respondents replied that their housing or household assets have improved. The rather small impact is expected, since capital accumulation is important before changes in housing or household assets, yet the roads have been newly constructed.

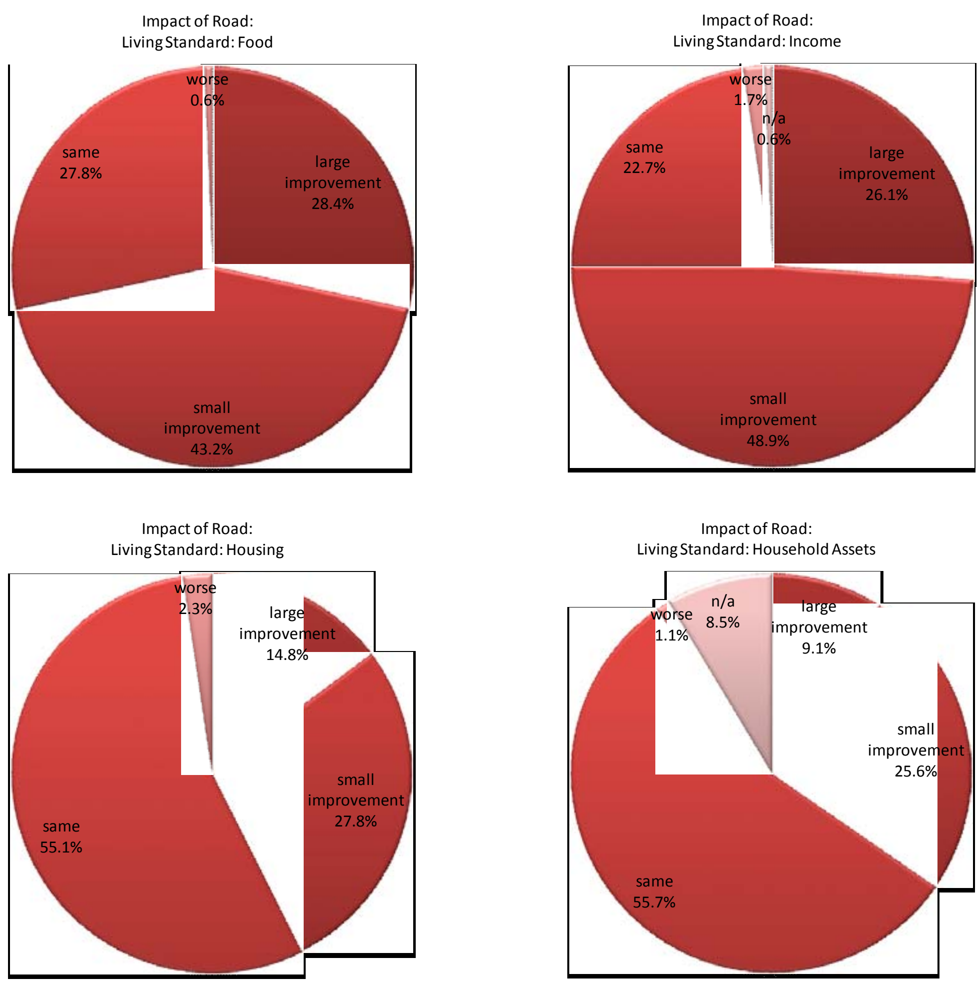


Figure 4.9: Respondents view on the impact of road on standard of living after the road construction

Some of the roads were barely a few months old. Rather high share of positive response for housing as compared to household assets indicate that, despite higher costs, housing investments are possibly seen as a more durable and useful investment as compared to luxury assets such as televisions. Increases in the use of NGOs were also relatively small, with only 33% mentioning an improvement. More than 50% of the respondents do not use NGO services.

Impact of Road:
Living Standard: Use of NGO

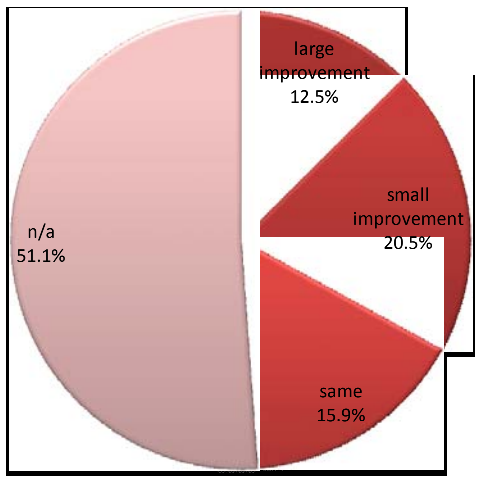


Figure 4.9 (cont.): Respondents view on the impact of road on travel behavior after the road construction

The final set of variables to understand the impact is the economic ones. Among the number of businesses, 29% were established after the construction of the roads, which is a significant share, especially since construction some of the roads has been completed only recently. Although 40% of the households do not participate in any microfinance schemes, participation in microfinance programs has increased significantly since the construction of the roads (Figure 4.10).

Impact of Road:
Use of Microfinance

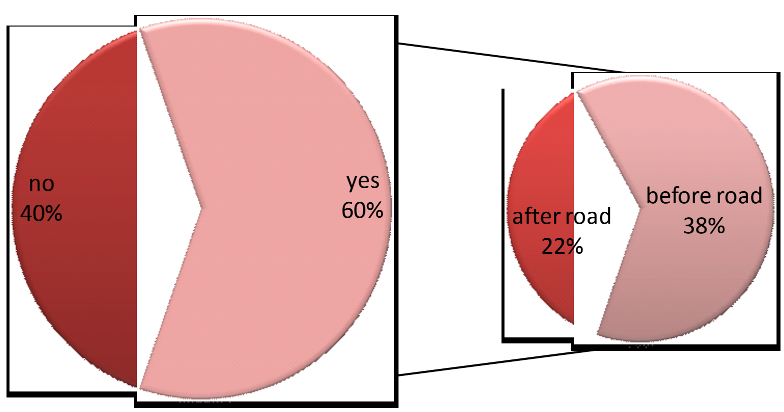


Figure 4.10: Respondents view on the impact of road on use of micro finance before and after the roads

Findings related to transport costs is interesting. 21% of the respondents mentioned that travel costs has decreased since the construction of the roads, whereas around 30% have mentioned that out of pocket travel costs have increased. This appears in contradiction with the expectation that travel costs should decrease. However, the primary reason for the increase in travel costs is because of higher use of rickshaws or other paid modes on the new roads, whereas previously walking was the only possible mode, with no out of pocket costs. All the respondents do mention that there was a large reduction in travel time. Including the travel time reductions in travel costs would possibly result in savings in generalized travel costs. Also, that these households quickly switched to paid modes of travel indicate there was a large suppressed demand for them, which was fulfilled by the new roads. Most respondents maintain that personal travel and goods transport have become more convenient.

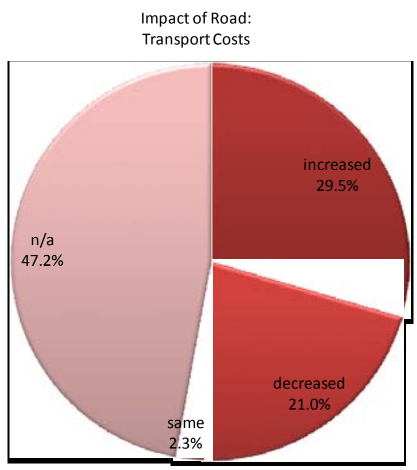


Figure 4.11: Respondents view on the impact of road on travel costs after the road construction

The response rate for the question on land value increases was 52%. Those who did respond, mention that land value has appreciated by between 7% and 900%, which is a very large range (Figure 4.12).

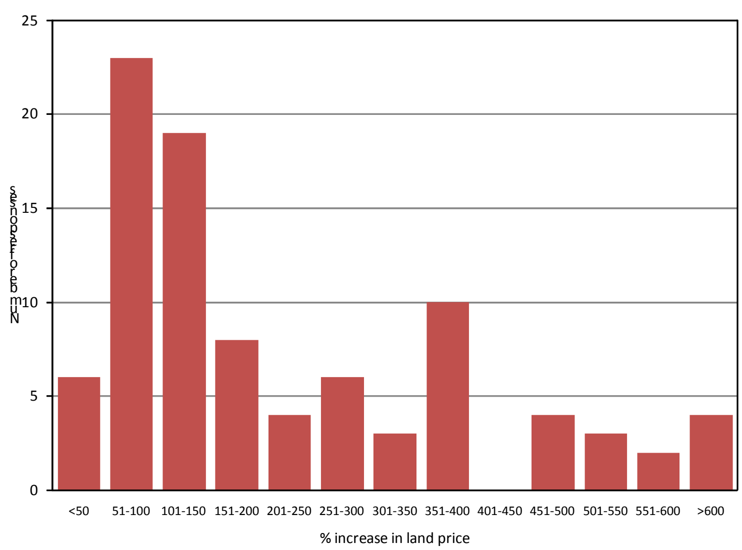


Figure 4.12: Increases in land value as described by the respondents (52% response rate)

Although a wide range is expected due to the differences in the time since completion of the different roads, the range is still very high. The consultants therefore opt for median, instead of mean, to express the general increase in land value. The median increase in land prices was 150%, while mode was 100%. However, several caveats remain in these numbers. Firstly, the increases include the natural increases in land prices, so the impact of roads is smaller than these numbers. Secondly, as mentioned early, the respondents were generally not good at providing quantified answers. Nonetheless, considering the large increases described by the respondents, it can be safely concluded that there has been an appreciation in the land value that can be attributed to the new roads.

Overall, the survey results from all households show that the newly constructed rural roads, rigid or block, had large benefits to the society.

4.4.2 Block vs. Rigid Pavements

As mentioned earlier, there were two types of roads constructed by the LGED in the region: one is the all weather rigid pavements and other is the submersible concrete block pavements which follow the existing grade and remain inundated during the rainy season (Figure 4.13). Since one of the major tasks was to understand the impact of the block pavements, it was important to identify if there are any large differences in impacts between the rigid and the block pavements. The survey aimed to collect information from equal number of respondents using each type of roads and 44% of the completed questionnaires were from the users of the block pavements.

Figure 4.13: Rigid and block pavements

Instead of investigating every impact variable in Table 4.1 to find differences between the impacts of the two road types, the consultants narrowed down to eight variables: opportunities to employment, access to health services, women's mobility, trips by rickshaws, food consumption, income, new businesses and increase in land value. Figure 4.14 presents the differences in column charts.

Respondents felt that rigid pavements offer marginally higher opportunities to employment as compared to block pavements. Although a marginally larger share of block pavement users mention that the new road has vastly improved access to health

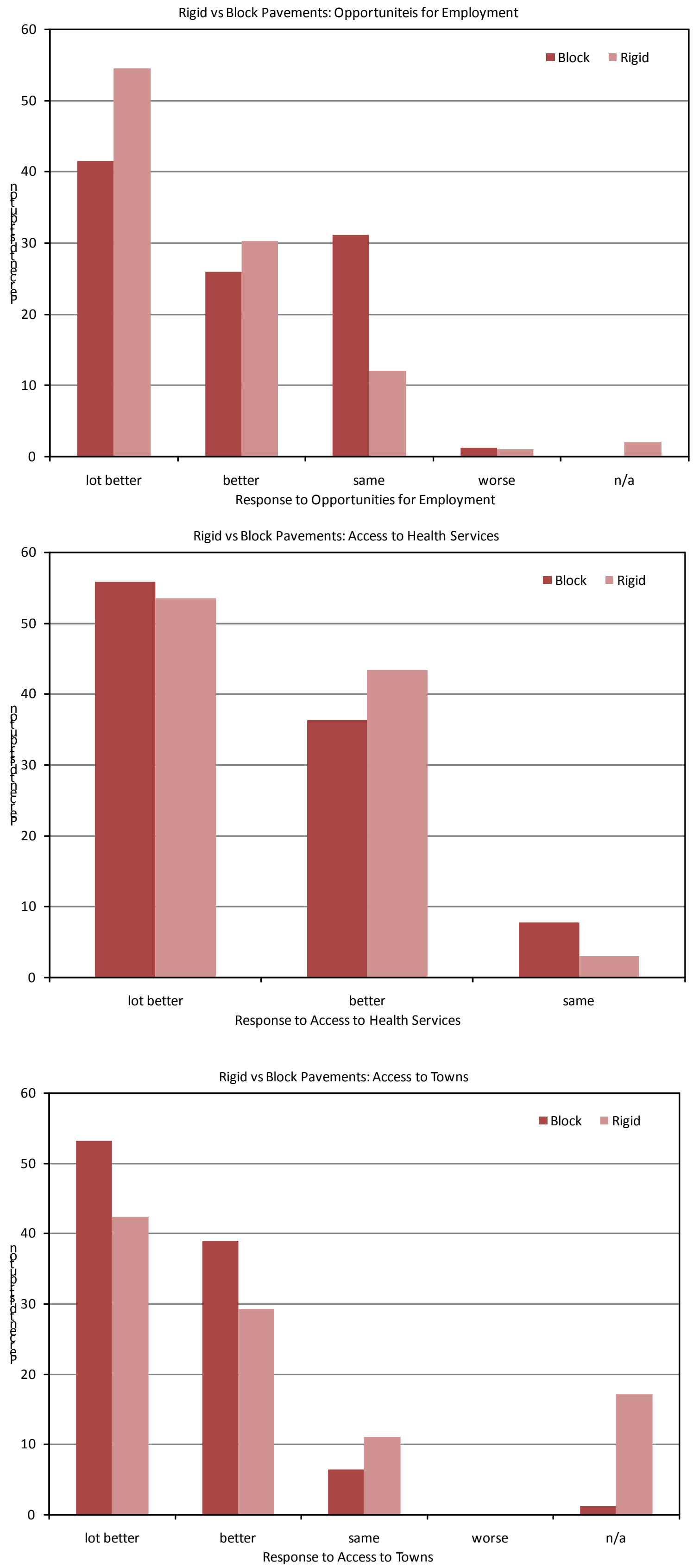
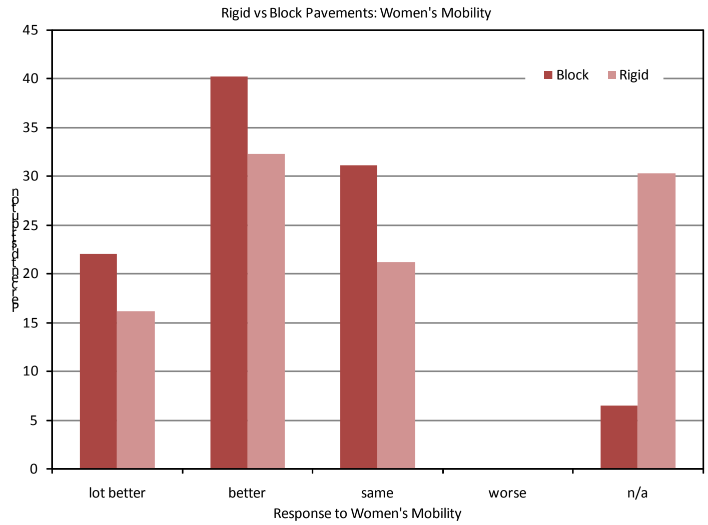


Figure 4.14: Comparing the impacts of rigid and block pavements

services, in comparison with rigid pavement users, the difference is possibly insignificant. Access to town is one variable where block pavement performs better than rigid pavements. A larger proportion of block pavements users find that the roads have improved access to towns. Women's mobility is another response variable, where the block pavements appear to do better than the rigid pavements. However, the n/a response for rigid pavements may have biased the results and the differences possibly is negligible for practical purposes.



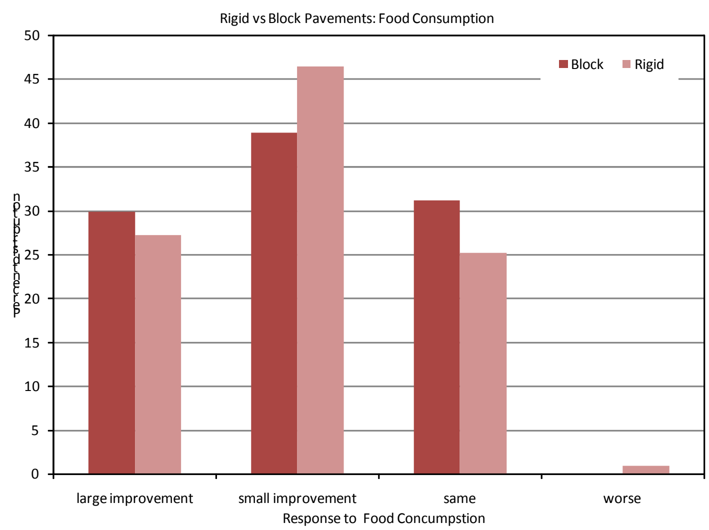
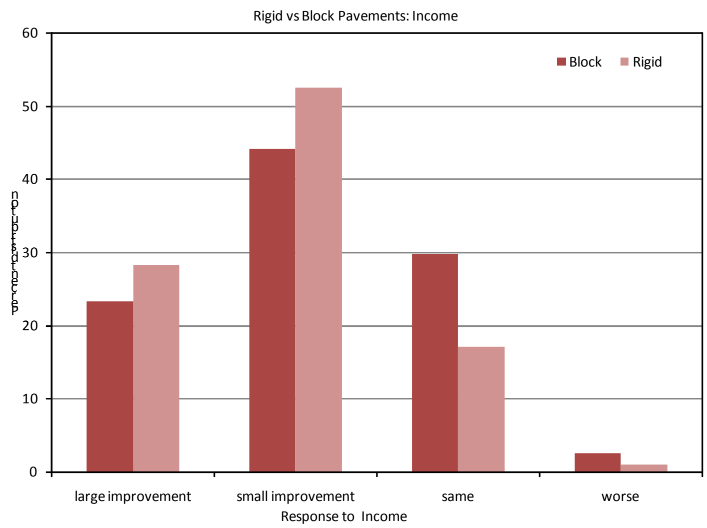


Figure 4.14 (cont.): Comparing the impacts of rigid and block pavements

Block road users register marginally higher response in the 'large improvement' category for food consumption, but slightly smaller response in the 'small improvement' category. Income shows a consistently lower response for block pavement users. Land near the blocked roads registered a larger price increase as compared to those near the rigid pavements (median 154% vs. 120%). Block roads also spurred more new businesses as compared to rigid pavements. There was a 47% increase in businesses among households near the block roads, whereas the number is 36% for households near rigid pavements. Given the lack of consistency in the differences (which are also marginal) between the impacts of two road types and considering other geo-spatial explanations for some of these differences, it can be safely concluded that there is no systematic difference in the socio-economic impacts between rigid and block roads.



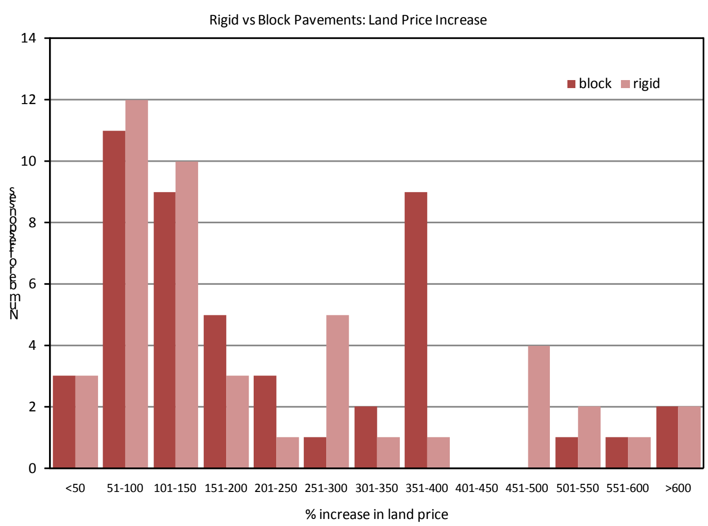


Figure 4.14 (cont.): Comparing the impacts of rigid and block pavements

Of special interest was the involvement of the local people in the construction of the block and rigid pavements. Around one-thirds of the respondents using the block roads were involved either during construction or maintenance of the roads, whereas the share is one-fourths for the rigid pavement users. This indicates that block roads possibly employ more local people, which is expected because of its LCS type of project delivery. There was, however, no significant difference among the women involvement in construction and maintenance of the two types of roads. Although block roads directly employ local women for construction of the blocks, it appears contractors of rigid pavements also employ local women as labor.

4.4.3 Impact of Time since Completion

The results above are combined results for all roads. However, the roads have been constructed at different times. Since the impacts may lag the construction of the roads, it is possible that the impacts will differ by the construction years. A priori, it is expected that respondents will hold a more favorable view for those roads that were constructed earlier, since sufficient time has passed to realize the full impact of those roads. Also, if impacts are indeed larger for earlier roads, then it can be concluded that the final impact of all the roads will be larger than that mentioned in this report. In order to investigate this, the roads have been clustered intro 3 groups depending on their year of completion (2005-2006, 2007-2008 and 2009-2010). Four impact variables: opportunities to employment, access to health services, food consumption and income have been chosen to understand the possible differences in impacts. Figure 4.15 presents the percent of respondents who mention that there was an improvement (small or large) in the impact variable for all three groups. It is clear that the respondents had more positive views about the effect of the road when the roads are older. In all four impact variables, roads that were constructed the earliest have recorded the maximum share of positive responses from the users. More recent roads generally registered less favorable views, which is expected since there has not been sufficient time to realize the full potential of the roads. This indicates that the final impact of the roads after a few years will be larger than the findings here.

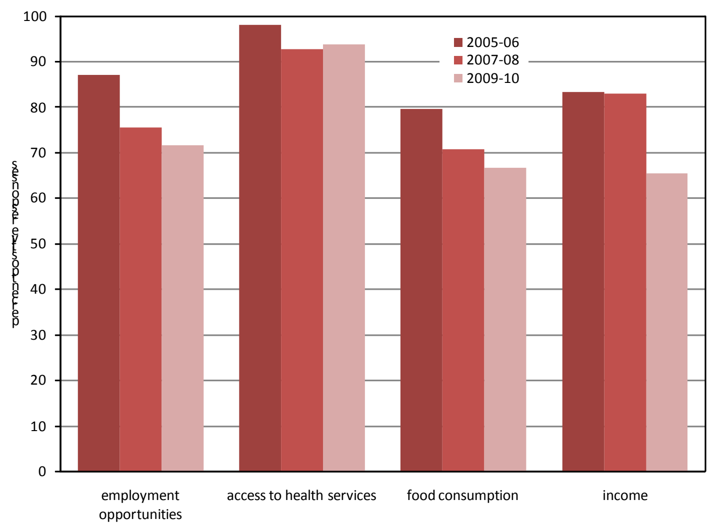


Figure 4.15: Influence of time since road completion on various impact variables

4.4.4 Recommendations from the Respondents

In addition to the structured questions, there were two additional open-ended questions for the respondents seeking their views about any negative impacts of the roads and about potential improvements on existing roads. Unsurprisingly, out of 176 responses there were only 10 responses identifying negative impacts. Apart from four concerns about loss of trees and five concerns about loss of some land, the negative impacts were negligible (e.g. one mentioned that theft increased since thieves can now escape quickly!).

Recommendations for improvement were more frequent. The major improvements suggested by the respondents are (in descending order of importance):

- Widen existing roads
- Enhance the network for better connectivity (to other major roads, rivers, markets, marshes)
- Make surfaces smoother (block to rigid, rigid to bitumen)
- Elevate the roads
- Pave the unpaved parts
- Maintain regularly
- Plant trees

Figure 4.16 represents the number of respondents supporting these recommendations. Note that one respondent can have more than one suggestions for improvement.

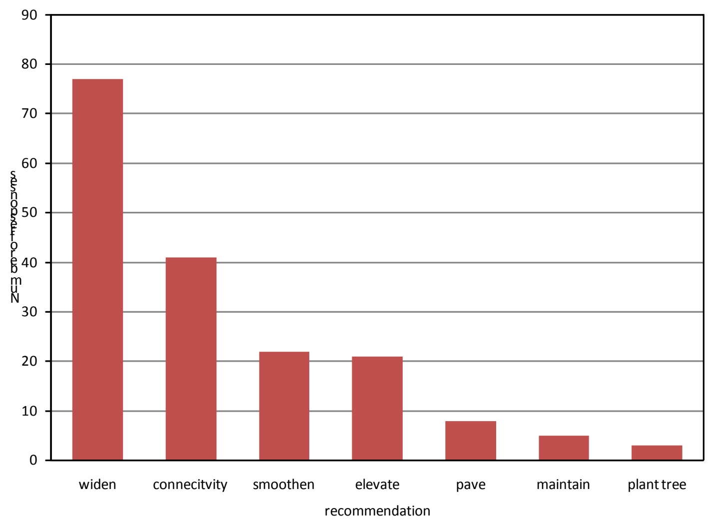


Figure 4.16: Suggestions by the respondents to improve the roads

4.5 Summary

The questionnaire survey results indicate that the roads have clearly had positive impact on the livelihood of the people in the areas they were meant to serve. Respondents held positive or neutral views on all the impact variables. There was no significant or systematic difference between the impacts of rigid or block pavements. This indicates block pavements were as beneficial as rigid pavements and there is no immediate need to replace the block pavements with rigid pavements, unless technical reasons dictate so (e.g. heavier vehicle loads). In many regions surveyed, the new roads have been constructed only recently and the overall impact would be larger than what is reported here, once these roads mature.

Chapter – 5

Geotechnical Study of Block Paved Road

5.1 Introduction

Concrete block paved roads are not very new in the history of paved roads construction. But the use of this technique at Sunamganj, Bangladesh is unique due to several reasons. Firstly, the region remains under water for a significant part of a year. The blocks remain in place under water during that time of the year without any visible damage. Secondly, the blocks are constructed employing the villagers using a unique "Labor Contracting Societies", which enhances the local social facets in a dramatic way. Thirdly, it is maintained by another innovative local road-segment ownership method. Consultants of BRTC, BUET have undertaken the task of conducting an all-around study of the block-road. This part of the report will elaborate the geotechnical advantage, disadvantage and improvements of the block paved roads.

5.2 Objectives

The objectives of this study are :

1) Block geometry optimization for better performance in terms of long term stability. In this regard, effect of (i) Block size, (ii) Block shape and (iii) Block depths on bearing capacity and settlement are studied.
2) Improving riding quality by improving block to block locking mechanism.

5.3 Laboratory Investigation

A detailed laboratory investigation was carried out on the soil samples and blocks collected from two places of Sunamganj. One place was Haluaghat Moinpur road and the other was Voisharpar East, Shahebnagar Road. Two blocks along with soils beneath those blocks were received in our laboratory in a sealed container.


Soil Samples Collected from Field


Block Samples Collected from Field

Both geotechnical and concrete quality investigation were carried out simultaneously on those samples. Some of the results are summarized in Table 5.1. All other results are attached in the Appendix-B of this report.

Table 5.1: Results of Laboratory Investigation on Soil Samples

Place / Name of tests	**Direct shear (dry)**	**Direct shear (soaked)**	**Liquid & Plastic Limits**	**Specific gravity**
Haluaghat Moinpur road, Block-1	C=9.09 kN/m^2, φ=38^o	C=8.42 kN/m^2, φ=32^o	LL=34, PL=23	2.67
Haluaghat Moinpur road, Block-2	C=10.42 kN/m^2, φ=34^o	C=9.87 kN/m^2, φ=32^o	LL=30, PL=20	2.64
Voisharpar East, Block-1	C=6.0 kN/m^2, φ=37^o	C=7.98 kN/m^2, φ=32^o	LL=28, PL=18	2.61
Voisharpar East, Block-2	C=7.98 kN/m^2, φ=32^o	C=7.54 kN/m^2, φ=34^o	LL=27, PL=20	2.61

5.4 Numerical Analysis of Single block

A three dimensional Finite Element (FE) Analysis is carried out for single block surrounded by soil. The block is considered to be made of concrete of appropriate strength and it is modeled by linear elastic concrete parameters. Surrounding soil is considered to be a mixed silt type soil and modeled by nonlinear elastic-perfectly plastic material parameters. The analysis is carried out using a 3D FE analysis package called "Plaxis". Concrete strength is considered to be 1000 psi (lowest possible value). Soil parameters are determined from laboratory tests results, which came out to be C=10 kN/m^2 and φ=25 deg. A line load of 200 kN/m is applied in the middle of the block along the shorter side. Actual load on any block is about 20 kN/m. The geometry of actual block is 9x15x6 (BxLxd) inches. Table 3.2 shows the various block sizes for the parametric study. Figure 5.1 and 5.2 shows the Finite Element meshes used for the analysis of single block for the parametric study.

Table 5.2: Variations of the Block Geometry for the Parametric Study

Type of variations (Serial)	**Size-variations, Depth=6 inches (inches)**	**Shape-variations Depth=6 inches (inches)**	**Depth-variations BxL=9x15 inches (inches)**
1	2.25/3.75	3/15 --> 0.2	2
2	4.5/7.5	6/15 --> 0.4	4
3 (Field)	**9/15**	**9/15 --> 0.6**	**6**
4	12/20	12/15 --> 0.8	8
5	15/25	15/15 --> 1.0	10
6	18/30	xxxxxxx	xxxxxx

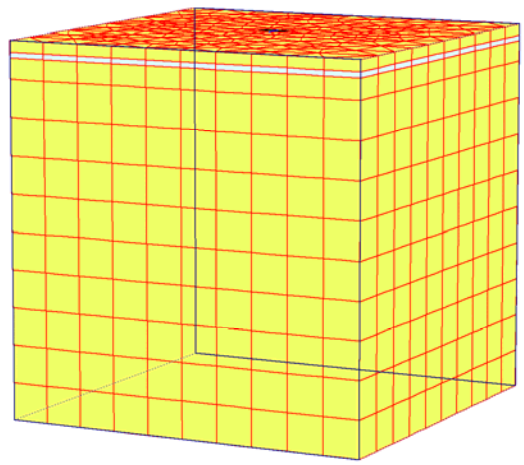


Figure 5.1: Three Dimensional Mesh used for the Analysis of Single Block

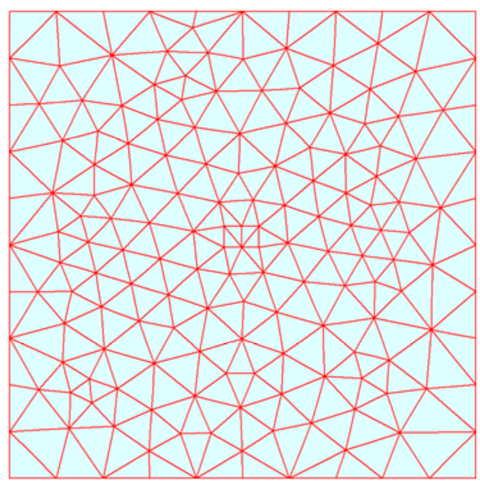


Figure 5.2: Two Dimensional Top View of the 3D Mesh used for the Analysis of Single Block.

5.4.1 Results of the Analysis of Single Block

The results of the parametric analysis are shown in Figures 5.3 through 5.8. The Figures 5.3 and 5.4 show the effect of (1) block size, Figures 5.5 and 5.6 show the effect of (2) block shape and Figures 5.7 and 5.8 show the effect of (3) block depths on the applied load (bearing capacity) of those blocks. Figures 5.3, 5.5 and 5.7 show the variations of applied load versus vertical displacement along the middle of long section of the block. Figure 5.3 show the variation of applied load versus vertical displacement for the block size and it does not have any lasting effect. The same result is observed for the case of block shape analysis result. This variation is pronounced only in the case of very thin block. Due to the thin formation of the block, its load-displacement curves vary a lot along the middle section, indicating the possibility of uneven settlement in course of time. From the observation of the Figures 5.4, 5.6 and 5.8, it is clear that the effect of size of the block is highly pronounced. The effect of block shape and block depth are not so pronounced at this stage of the analysis. Although theoretically there are effects of block shape and block depth, but considering the conservativeness of this analysis, these effects can be safely ignored.

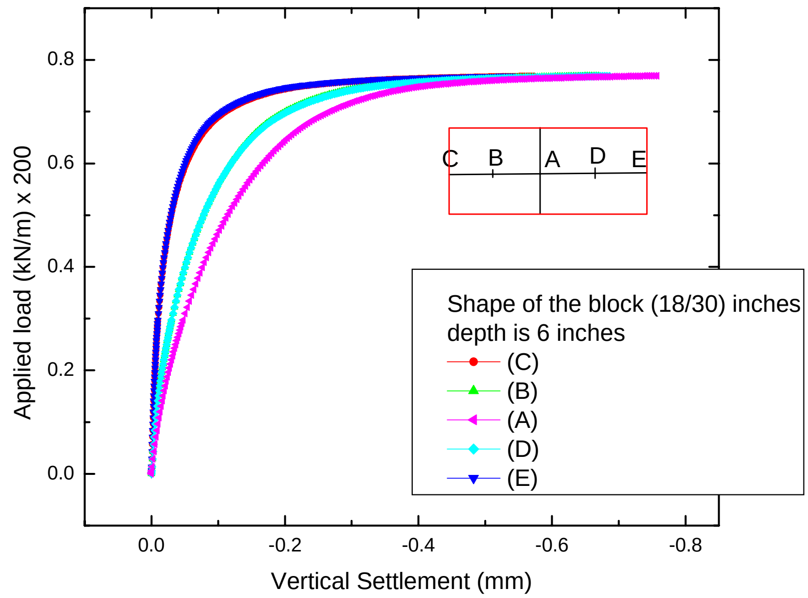


Figure 5.3: Variation of applied load with vertical settlement for biggest block size along the middle of long section of the block (marked A,B,C,D,E)

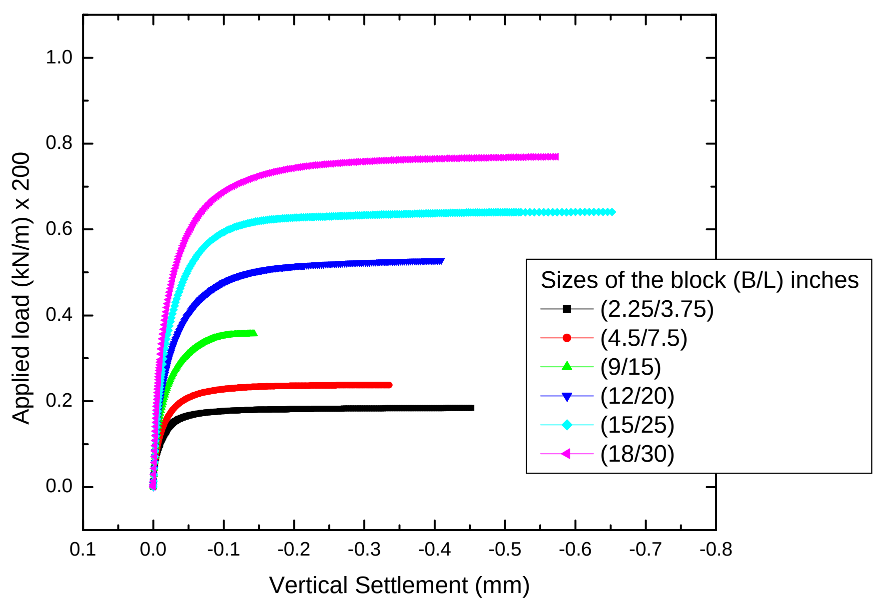


Figure 5.4: Variation of applied load with vertical settlement for various block sizes

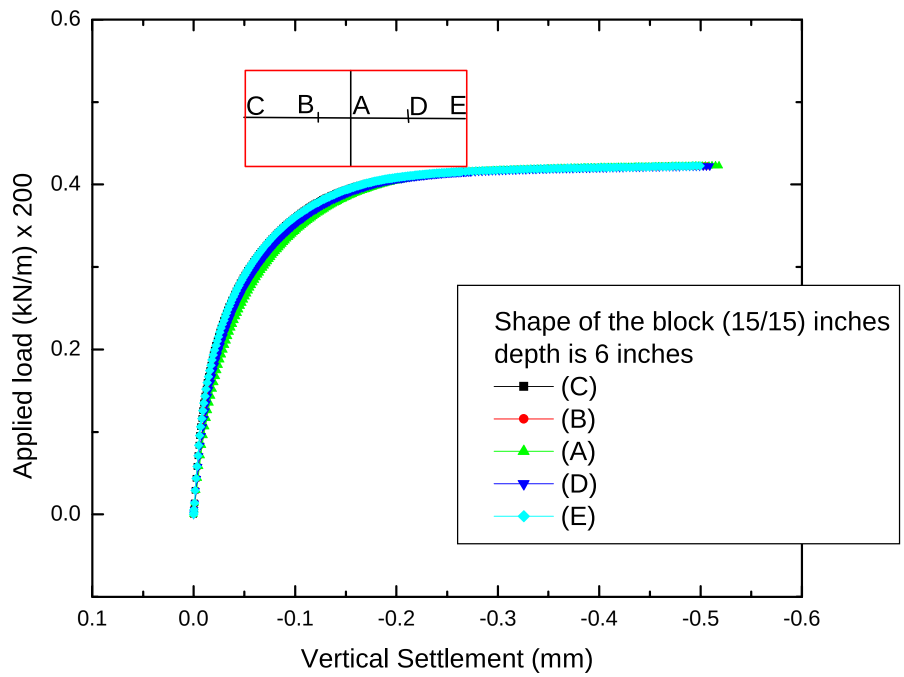


Figure 5.5: Variation of applied load with vertical settlement for square block shape along the middle of long section of the block (marked A,B,C,D,E)

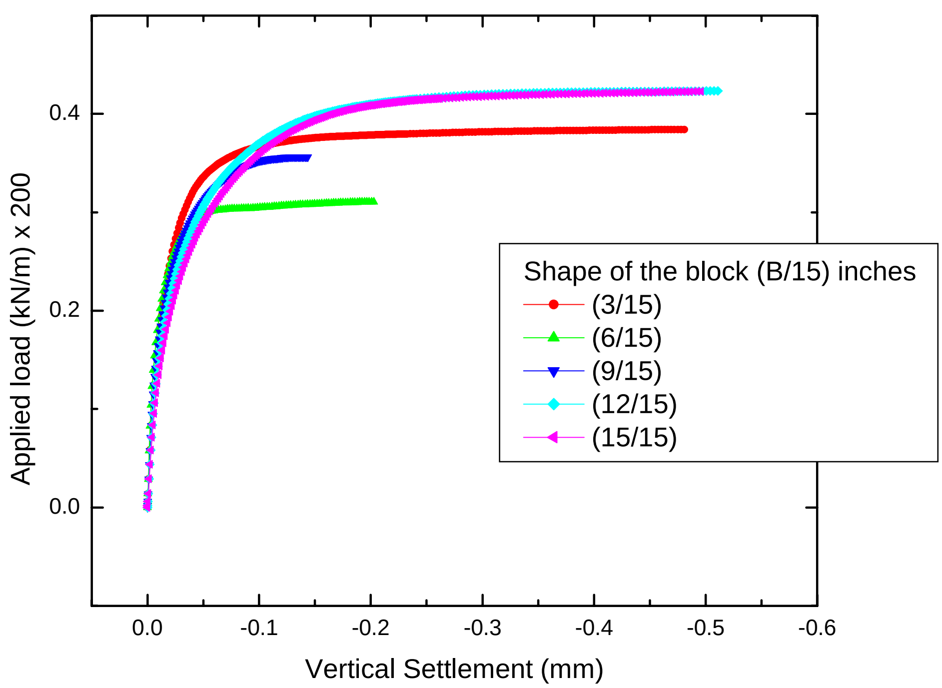


Figure 5.6: Variation of applied load with vertical settlement for various shapes of blocks

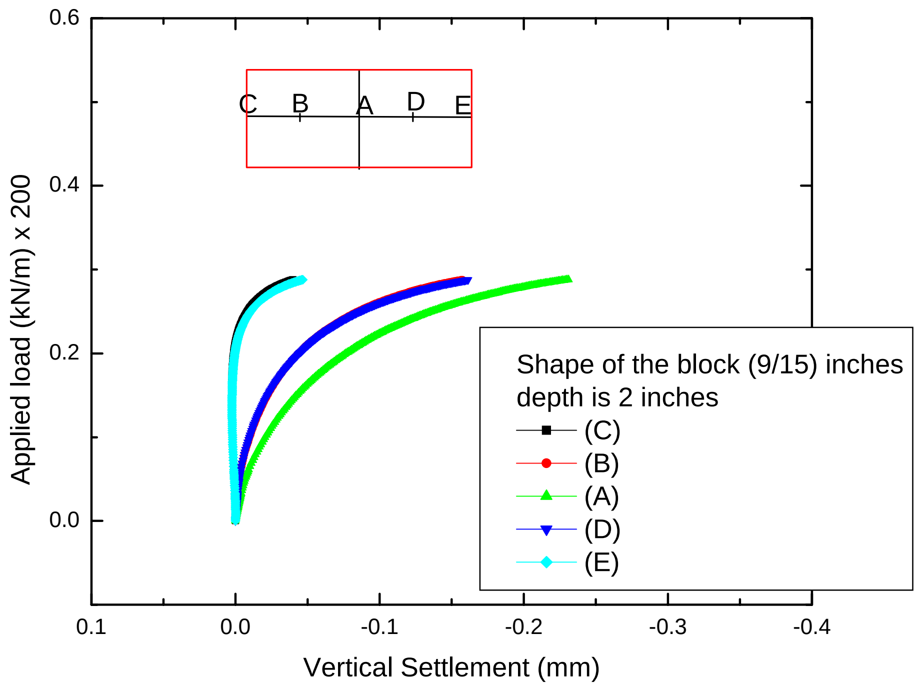


Figure 5.7: Variation of applied load with vertical settlement for the thinnest block along the middle of long section of the block (marked A,B,C,D,E)

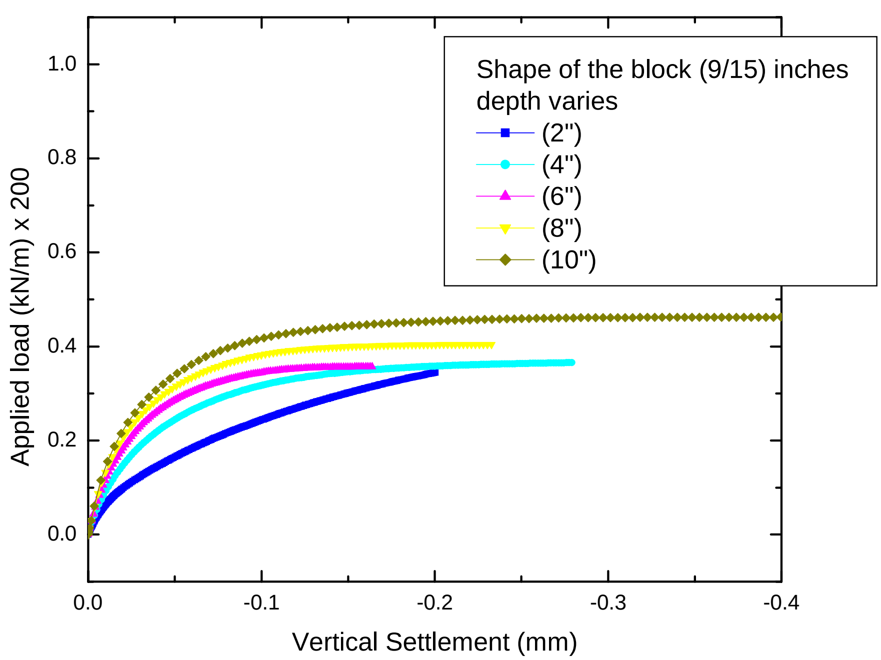


Figure 5.8: Variation of applied load with vertical settlement for various depths of blocks

5.5 Analysis of a Road Section

In order to complete the analysis, a section of road is taken for the three dimensional analysis. The section is shown in Figure 5.9. The section is consisted of blocks of standard sizes (9”x15”x6”). Blocks are jointed by a very weak mortar. Figure 5.10 shows the results of the analysis. It has been found that the road section can carry much higher load. It can marginally carry the LGED designated load (8.2 ton) for rural roads.

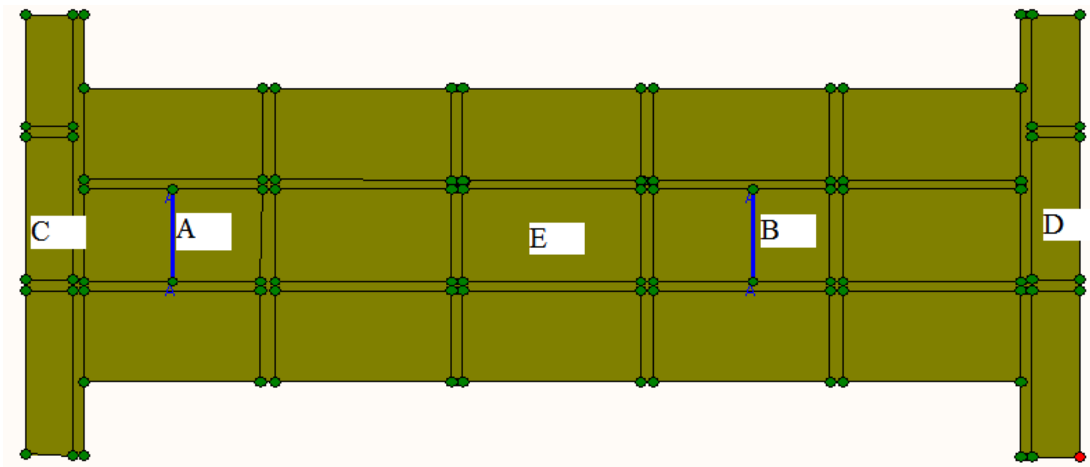


Figure 5.9: A typical road section taken for FE analysis

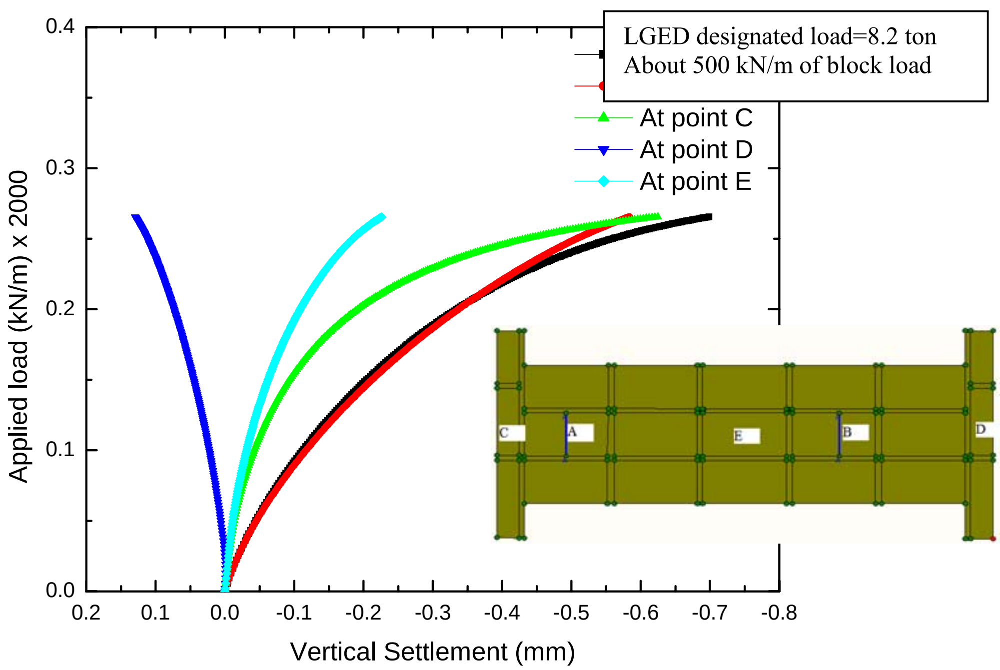


Figure 5.10: Variation of applied load with vertical settlement for a road section

5.6 Analysis of Locking Mechanism

One of the objectives of this analysis was to improve the riding quality of the block-paved roads at Sunamganj. In order to improve the riding quality of the road, it is necessary to improve the locking mechanism of the road. Currently blocks are jointed by mortar of 1” thickness. It can be improved by designing the blocks with a particular sloped side. A Finite Element parametric study is conducted on the effect of side slope of the blocks on the bearing capacity of the block. A 2D analysis is carried out for six side slopes. A typical locking mechanism with its FE representation is shown in Figure 5.11. The Figure 5.12 shows the deformed shape of the block-road section in amplified scale.

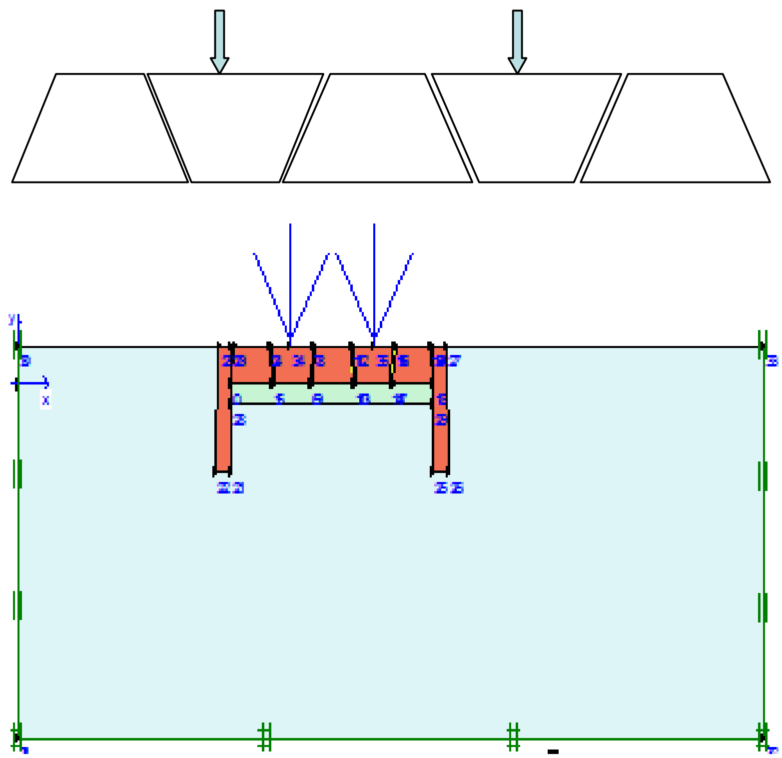


Figure 5.11: A 2D road section taken for FE analysis

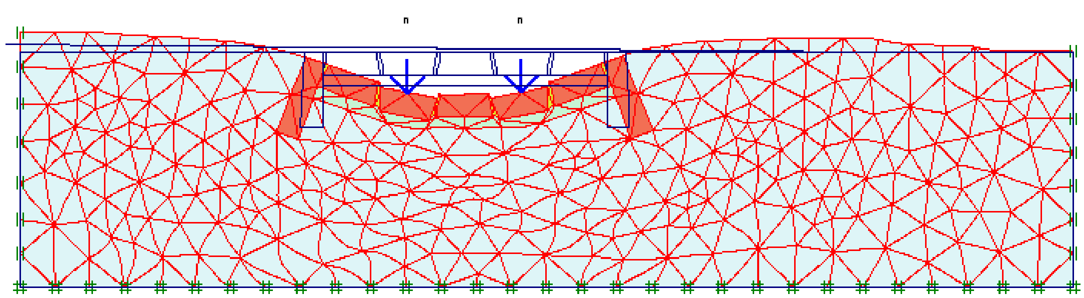


Figure 5.12: A 2D road section deformation pattern after the ultimate load is applied

Figures 5.13 and 5.14 show the effect of slope on the bearing capacity of the blocks. It is obvious from these figures that the bearing capacity increases exponentially with the increase in slopes of the sides of the blocks. But with the increase in slope of the block, its vulnerability of breakage will also increase. So it will need some field trial, before deciding a particular slope.

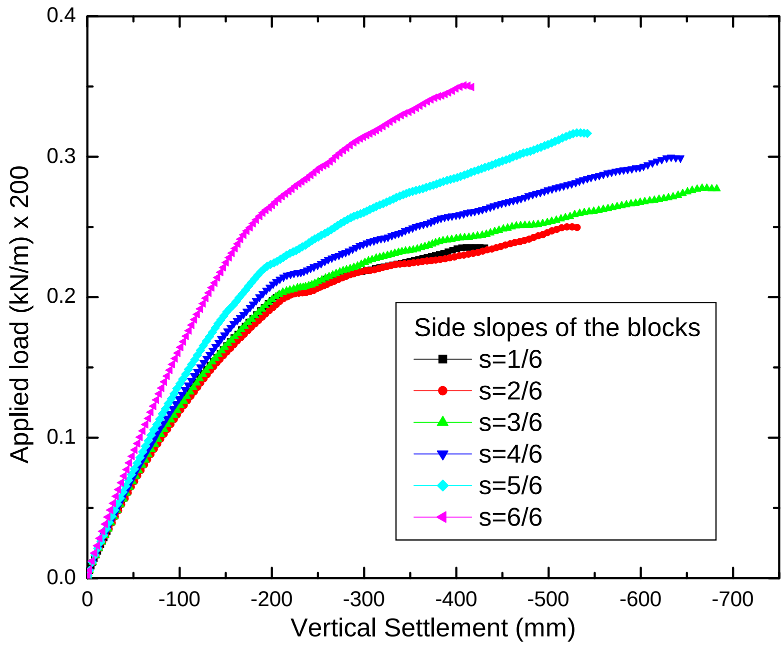


Figure 5.13: Applied loads versus vertical settlement for various side slopes of blocks

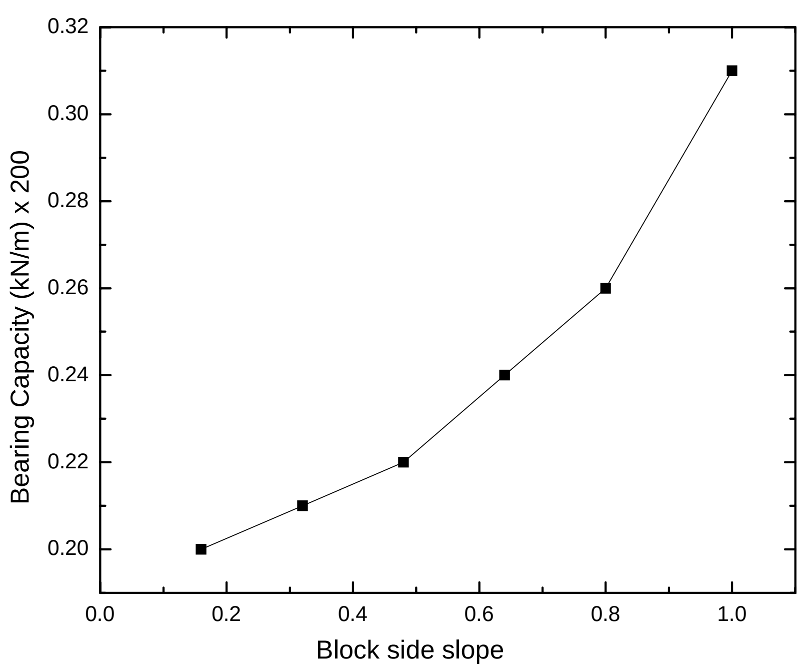


Figure 5.14: Bearing capacity versus side slopes of blocks

5.7 Development of a Design Procedure

Figure 5.15 shows the variation of block settlement with its surface areas. It has been understood that settlement increases at a faster rate up to the block size of 12”x20”. After that rate of settlement increase remains constant. Figure 5.16 shows the variation of block bearing capacity with its surface area or weight. It has been observed that the actual load on the block pavement is far below the smallest block. So the bearing capacity of the current block is underutilized. It can be seen from the top axis of the figure that weight increases along with the increase in bearing capacity or surface area. The current block has a weight of 32 kg. The next size is 12”x20” but it will have a weight of 58 kg, which may not be suitable for carriage by human labor.

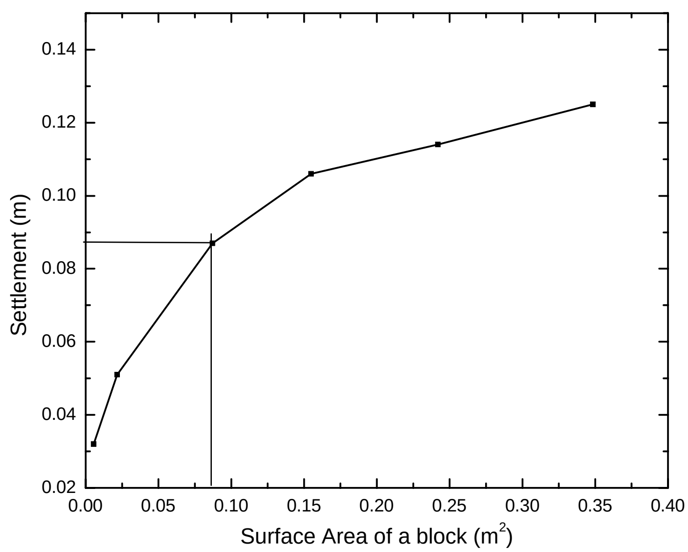


Figure 5.15: Variation of settlements with surface area of blocks

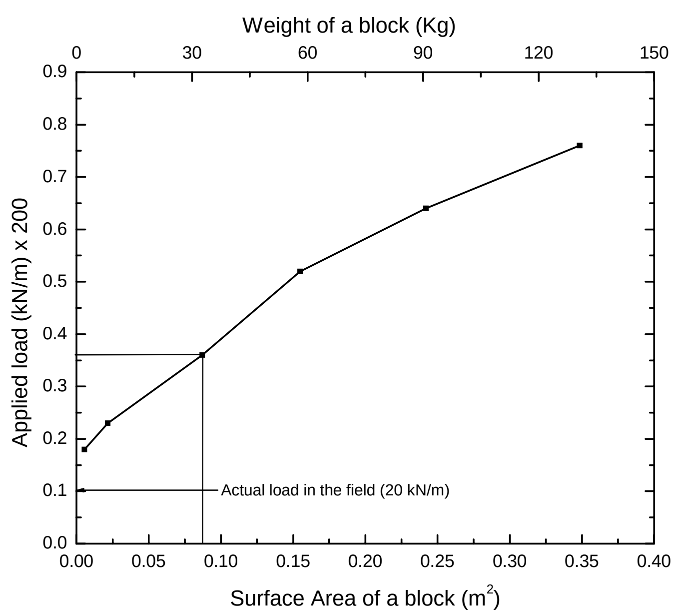


Figure 5.16: Variation of applied loads with surface area/weights of blocks

Figure 5.17 shows a unique way of designing blocks considering its size, depth, weight and bearing capacity. Any of the three axes can be starting variable for the design. As for example, someone starts for a 40 kg block, then he has a choice of taking either 2” depth block with corresponding size on the bottom axis and bearing capacity on the right. Similarly he might choose 4” depth as well with a different size of the block and bearing capacity. In this way, a block designer may have a plethora of options for the size, depth, weight and bearing capacity of the blocks.

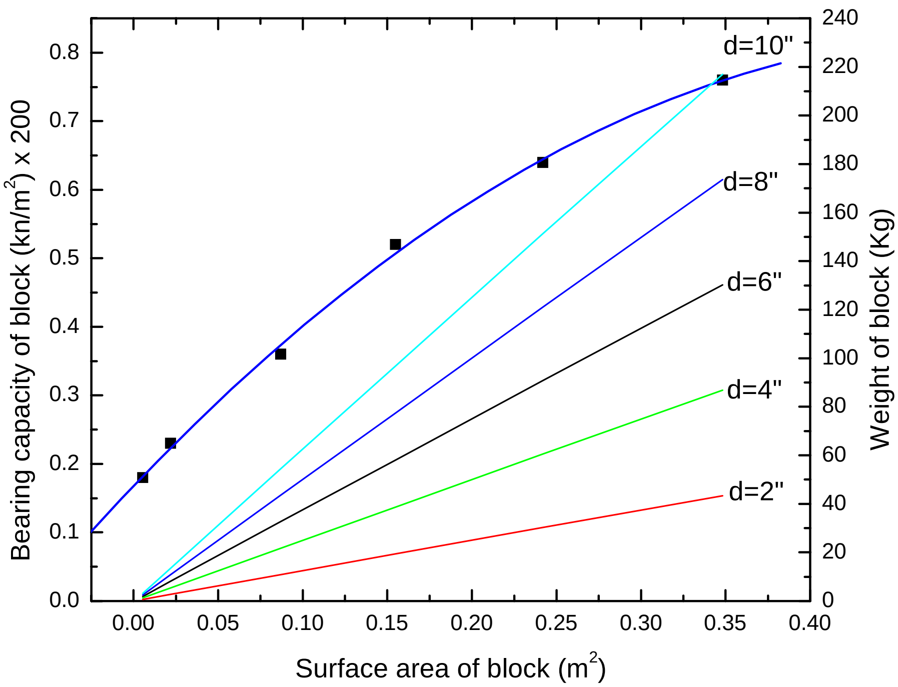


Figure 5.17: A design graph for blocks

5.8 Summary

From the discussion of the analysis of the results, it is clear that size of the blocks has the most prominent effect on the bearing capacity and settlement of the block. Increase in block size will increase the bearing capacity, reduce the settlement and hence increase the riding quality to some extent. But the increase in weight will create distress among the labor. The current size of the block is just right in size. However, block size can be increased by reducing the depth to keep the weight good for LCS by using the design graph. Riding quality can be improved by increasing the side slope of the block, but it needs field trial before a particular side slope is approved.

Chapter – 6

Road Safety Aspects of Block Pavement Roads

6.1 Introduction

It is well established that for the development of village road, the best strategy is giving accessibility with adequate safety instead of providing mobility alone. Taking this in cognizance, during the field visits both rigid and block pavement roads of the study area were examined critically to understand the safety concerns that are associate with these two types of road and thereby to suggest safer accessibility and connectivity at village level. In this chapter observations on the roadway safety are documented followed by appropriate recommendations.

6.2 Degree of Exposures of Village Roads

During the field visits it was observed that in general the village roads have very high level of hazardous exposures due to the following reasons :

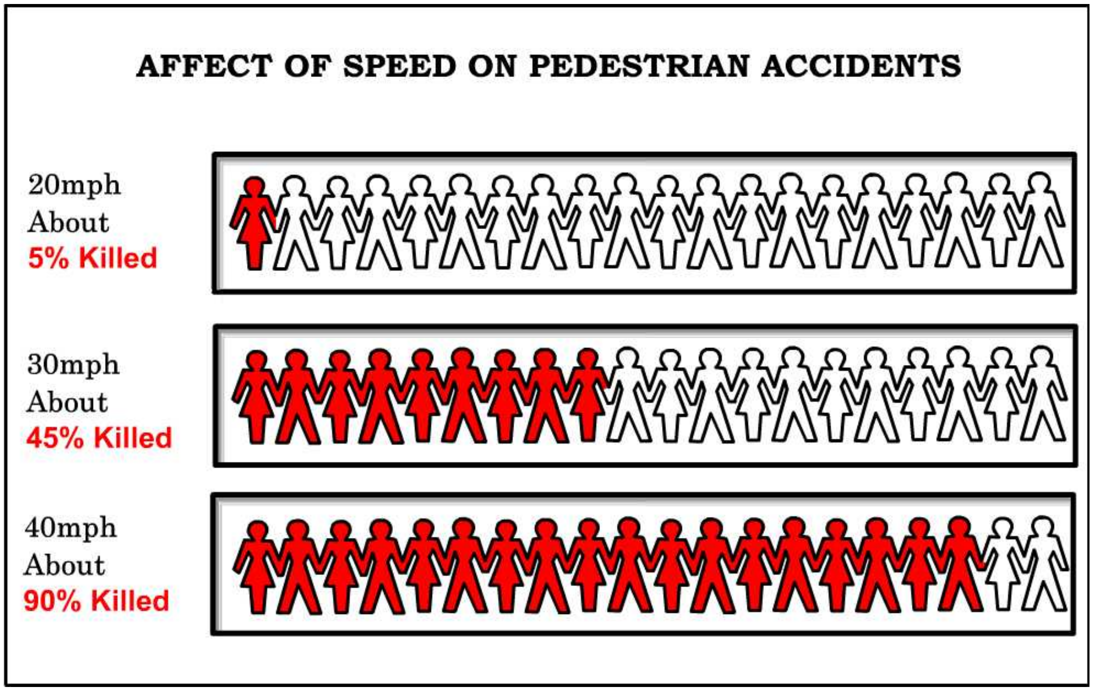
- Roads are often constructed bifurcating the neighborhood/homestead
- Often roads are found to be passes through very adjacent to the homestead virtually leaving no setback with the abutting properties
- In general roadway alignments are found to be unsafe with obstructed sharp bends and reverse curves
- Presence of frequent blind spots with obstructed vision particularly created by dense bushes/hedges and also due to presence of many obstructed driveways connecting roadside households
- Roads are built with very tight right of way and without adequate shoulder; resulting pedestrians are forced to occupy the same carriageway without any protection
- Absence of recovery area due to tight right of way
- Presence of high concentration of vulnerable road user groups like unsupervised children, old people with poor eye sights, pedestrians particularly with head load etc.
- Presence of roadside shops and grazing animals
- Often surprise situations are created by sudden
    - appearance of urchin chased by his mates
    - encroachment by pet dogs, cats, goats, cows etc.

- In the traffic composition, existence of large proportion of highly maneuverable motor cycle that are being used as commercial vehicles as well as high number of non-motorized and non-standard vehicles.

Few of the snapshots that were taken from the study areas to demonstrate the above mentioned degree of exposures are presented below.

Village Roads with high degree of Exposure

The above mentioned hazardous situations essentially suggest that the village roads should not be constructed primarily to give mobility rather should be built to ensure safer accessibility. Roadway planning and design should be such that it must be compatible with its environment. In particular, speed has to be controlled to ensure safety of the road abutting community. From the literature it is revealed that incompatible speed is the most single blamed cause of accident. As can be seen from the following Figure that increasing speed of vehicles is directly related to the number and severity of accident.



Since vehicular speed is directly associated with the riding quality of the pavement and to some extend related to the roadway alignment, objectively filed observations were made on vehicular speed particularly for motor cycle both on block and rigid pavements.

6.3 Comparison of Block and Rigid Pavements

Compared to block pavement, rigid pavement with relatively larger panel size reduces the number of joints and thereby naturally provides smooth and sweat-efficient riding surface particularly for the manually driven vehicles/carrier. The following photographs are taken to demonstrate this issue.



Moreover, due to less jerking and jolting problems associated with the cement concrete rigid pavement road, the rickshaw as well as rickshaw-van passengers particularly women, aged people and patients naturally preferred the concrete pavement. On the contrary, as the cement concrete brick block pavement road is made up with many joints and has differential settlement potential - its uneven and rough surface reduces vehicular speed and causes discomfort to both the pullers and passengers. Field observation revealed that traffic speed on rigid pavement is relatively significantly higher as compared to that of block pavement road.

In the study areas, the motor cycle is found to be the speediest mode of transportation among the traffic composition. Being a two wheeler vehicle, it is extremely maneuverable and has the potential to negotiate very tight right of way with high speed and thereby can provide high degree of mobility. Due to these attributes this mode is gaining popularity in rural area particularly among the young travelers as well as for longer trip makers. Most dangerous things are that the riders of these motor bikes are mainly young and teenagers who do not have driving license, have little road safety sense, and often made joy riding to enjoy the thrill of over speeding. But they do not know that ‘speed thrills as well as kills’.

In the absence of any enforcement measure, these young drivers find themselves outside the traffic rules & regulations and neither the riders nor the pillion passengers use helmet. Another striking safety concern is that now-a-days these bikes are being used to ferry passengers commercially and thereby inducing fierce competition attitude and over speeding tendency among the riders which makes the roadway operation most hazardous.

Field observation revealed that the average speed of motor cycle on rigid pavement road is about 38 kmph as compared to 23 kmph on block pavement road with similar road-traffic (geometric and operational) and environmental conditions.

Considering the fact that village road is very hazardous due to the presence of heterogeneous traffic, lots of non-standard vehicles, hardly any driver has driving training and license and most importantly due to the presence of large number of vulnerable pedestrians, safety must be given utmost priority in providing connectivity in rural area. That is why, though for the community, road with good riding quality is very important but for the planner it has to be a delicate balance between mobility and safety.

6.4 Case Study

In this study, though attempt was made to analyze accidents that are occurring on the roads of study areas but due to absence of accident recording and reporting system, it was not possible to carry out. Instead, the investigation was made based on the interview taken from one of the reported black spots of the study areas. From the field interview it was learned that accidents are occurring frequently and sporadically injuring mainly children, pedestrians and bike riders. Most blamed vehicle is found to be the motor cycle. Seeing the painful road accident incidences involving with innocent children, as a symptom oriented reactive measure community people are installing speed breakers at the accident prone road segments. As these speed breakers or speed calming devices themselves are made non-engineered and placed without any advance warning signs, these are acting as hazardous objects and inviting accident in different forms.

One of the accident prone locations (near MBC) can be seen from the following snap shots, where one fatal and one severe grievance typed accidents have occurred within one year period. It is to be noted that the road is made up of rigid pavement with good riding quality and straight alignment which are conducive for speeding of vehicles. After the incidents, with a view to control the over speeding vehicles- local people and road side shop owner have installed two speed breakers by their own cost and initiatives. It is also learned that after placing the speed breakers, subsequently two more incidences have occurred where in both cases motor cycles hit the speed breaker and become out of control injuring the riders and pillions. According to the shop keeper, these speed breakers are creating surprise situations particularly for the non-local road users who are not familiar with these obstructions. From the Photograph it can be seen that the speed breakers are not easily be distinguished as both the road segment and speed breakers are of same color and without any road marking resulting poor color contrast.

Besides limited user perception study undertaken among the road users revealed that the rigid pavement is more accident prone with high frequency and severity record than that of block pavement due to its improved riding quality as well as its over-speeding potential. According to their information frequency of accident is high at the sharp bend with obstructed vision, along the long straight segment of the road and also at the junctions. The most common types of accident are hit-pedestrian and skidding of motor cycle. In contrast as compared to the rigid pavement, relatively rough textures and uneven surface of block pavement acts as a self enforcing speed calming device and thereby found to be safer.

It is to be noted here that due to this inherent attribute, in safety engineering practice, as a counter measure the block pavement is recommended at the junction approaches as well as at the entry-exit of at-grade pedestrian crossings with poor accident record. The following photographs are presented to demonstrate the potential use of block pavement as speed calming device.

Which clearly demonstrate that the village roads with high degree of exposure should not be built ignoring the roadway safety concerns; rather while planning road in rural setting, mobility of travel should be compromised to uphold the "Safety First" policy. That is why it is recommended that block pavement should gainfully be used at the hazardous locations like driveways connecting road adjacent houses without any setback, bends, junctions, etc. as a speed reducer or calming device.

6.5 Other Safety Concerns

- Roads from more than one direction are found to be meeting at the untreated junctions i.e. without any approach flaring or widening. This type of simple junction configuration is not only unsafe for traffic operation but also very difficult to make turn by the vehicle especially that carries tree logs, bamboo etc.

Untreated Junction

- During the field visit it was also observed that village roads are usually given connection directly with the high standard RHD roads without any treatment. Field observations revealed that due to large elevation difference between LGED and RHD road embankments, at the interface most of the cases village roads meet RHD road with steep gradient which is bit dangerous for safe operation of traffic.

Side Road Entry with Steep Gradient

- Traffic control devices like road signs and marking which have the potential to control vehicular movements are found to be totally missing particularly at the hazardous locations. In order to improve safety situation, road signs and marking should be installed liberally.

6.6 Summary

Considering the present ground realities like roads have to be built through villages bifurcating the neighborhood and exposing the vulnerable road users, heterogeneous traffic mix has to be allowed to ply on the same tight right of way, motor cycle as a dominating commercial vehicle have to be accommodated and most importantly deployment of traffic enforcement personnel to these remote areas would not be feasible or practical, towards developing safer road in the rural fabric - strategies should be as follows:

- Instead of straight alignment curvilinear alignment i.e. a good blend of straight and curved segments should be adopted
- As far as possible sharp bend should be avoided

- All through road should not be built with good quality surface
- Combination of rigid and block pavement road would be the best hybrid system; where road environment would be compatible with relatively higher traffic speed building rigid pavement can be given preference over block pavement
- On the other hand, due to rough texture as the block pavement road has the potential to reduce speed as well as skidding problem of motor cycle, it should be used particularly at the sharp bend, driveways, shops and in between long straight segment of road to arrest speed.

Most importantly, in planning and designing safer village road, as a first step the block pavement similar to that is being used under the Community Based Resource Management Project (CBRMP)-LGED in the district of Sunamganj should be given preference over rigid pavement to make the road self enforcing in reducing speed and thereby to make safety as a built-in feature of the road. Since the block pavement has the step construction potential, if needed later on road can be upgraded easily.

Chapter – 7

Conclusions and Recommendations

7.1 Introduction

Sunamganj is a district in the north-east region of Bangladesh, one of the least developed countries in the world. A large portion of the district is covered by vast wetlands (locally known as haor, baors and beels). These wetlands allow good waterborne transportation during the rainy season, but transportation during the dry season is very difficult with walking the only possible mode. The region is also susceptible to flash floods almost every alternate year. Despite Bangladesh making good progress in connecting its remote villages to road networks, there was a lack of roads in Sunamganj because of the topography. Access to health services, education, business or job opportunities were limited during the dry season because of the long walking commutes, and the lack of good transportation made Sunamganj one of the poorest regions in the country.

The traditional way of building roads on elevated embankments could not be followed in this region because of the large water flow during the wet seasons and sparsely distributed communities. Initial experiments with at grade rigid pavements did not fare well because of pumping of soil from under the pavement during the wet seasons and eventual loss of grade support under the pavement in many places. Engr. Sk.Md. Mohsin of Local Governments Engineering Division (LGED) eventually came up with an idea of building submersible concrete block roads. These small rural roads are designed in such a way that they remain under water during the wet seasons, but become operational during the dry seasons. The project is the first attempt at constructing a submersible road in Bangladesh. It also innovatively involved the community in constructing the roads. The project employed destitute women in the region to build the concrete blocks during the wet season. Mobility, and thus job opportunity, of women in this part is very little and the project allowed the women to earn money, which they could save and reinvest. At the same time the blocks were sized such that they can be easily laid by local male labour. Involving local community also allows better maintenance of these roads.

This Chapter presents the findings field observations, socio-economic and technical evaluation of the project. The technical evaluation investigated the strength, durability and sizing requirements for better stability of the blocks, while the socio-economic evaluation investigated the impact of the roads on the community and whether these impacts vary from a similar rigid pavement. The findings are summarized below.

7.2 Major Findings

7.2.1 Based of Field Observations

By and large the roads under the study area are being constructed with very tight right of way (2.0m-2.6 m), where conventional roller is not possible to use for subgrade compaction. That is why, any kind of high quality road viz. flexible or rigid pavement would not be suitable to construct with this type of narrow right of way and poor support condition.

Considering the scarcity of stone chips and Sylhet sand and most importantly requirement of concrete strength is not so high, gravel or shingle and local sand can easily be used in making blocks. Use of graded round gravels, which has the potential to improve workability of concrete mix, in place of crushed angular stone chips, would be an effective as well as self enforcing measure in maintaining quality of concrete blocks.

Considering the information obtained from BUET concrete laboratory regarding the compressive strength of cylinder made up of brick chips, it is revealed that locally available brick chips can be used as an alternative of stones or gravel to reduce the cost of production keeping all other benefits of the existing concrete block technology. It is obvious though durability of concrete with brick chips would be lower than that of concrete with stones but considering the temporary nature of block pavement road, particularly for the coastal areas of Bangladesh where roadway facility is difficult to provide not only due to scarcity of stone but also daily submergence problem caused by the influence of tidal flow.

Problem associated with the RCC rigid pavement is that both construction and maintenance works are contractor dependent as it requires special skilled labor and equipment. That is why the rigid pavement is difficult to be built by involving ordinary community people like woman. Periodic submergence characteristics of the area essentially suggests that road type has to be weather resistant as well as easily be maintainable. As such, adoption of semi-rigid typed block pavement based road is found to be the most appropriate and condition responsive.

From the non-destructive rebound hammer test results, average compressive strength of the blocks was found to be 2140 psi or 14.75 MPa with average mean error of 646 psi or 4.45 MPa. The observed strength is not up to the level which it should have been. Compressive strength test of 12 core specimens revealed that the average strength of concrete blocks is only 720 psi or 5.96 MPa, which is well below 18 MPa design strength. Most importantly it was observed that for all 12 core specimens the mode of failure was ‘mortar’, which definitely suggests that cement as a binding material could not impart properly in gaining intended strength of the concrete.

During the field survey it was observed that submergence of water did not affect the structure of the block pavement road significantly. It was seen that the damaged part of the road could easily be made usable by routine maintenance. This essentially suggests that the block pavement has the potential to serve the community sustainably withstanding the forces of natural.

Considering the inherent periodic submergence, traffic loading conditions and various short comings, it appeared that HBB type pavement system would not be an improvement over the submersible concrete block pavements in the haor areas.

The submersible concrete block pavements can offer a viable adaptation measure by allowing the water to flow unhindered. This would encourage quicker retreat of cyclone and flood water.

Life cycle cost comparison shows that RCC road would be more appropriate for upazila road; whereas block type pavement system would be suitable for village and union standard roads. Besides, as compared to the cost of bituminous pavement, the CC block based road would be economical even for higher standard upazila road.

7.2.2 Based of Socio-Economic Study

Results for all households indicate that the roads have positive impacts on all our impact variables. Almost all the respondents answer positively on the ease of access and mobility variables. An overwhelming 95% of the respondents replied that there was an improvement in their access to health services. Discussions with the respondents indicate that road has enabled the sick to use rickshaws to go to health services. A large majority of 87% of the households felt access to school were better due to the new roads. Especially, 64% of the respondents believed that access to markets vastly improved due to the roads.

More than 50% of the respondents felt that women's mobility has improved after the roads. A significant proportion, however, still feels that the question does not apply to them because the women do not travel to towns or markets, or did not answer. More bicycle travel was undertaken by almost half of the households. Around one-fourths maintained status-quo with bicycle travel, while 4.5% travelled less by bicycle now. An overwhelming 93% of the households increased their travel by rickshaw. This is no surprise since rickshaws require a smoother surface than motor cycles or bicycles, and new roads significantly increased the supply of smoother riding surfaces as compared to the earthen roads. More than 70% responded that food consumption has improved, of which almost 40% indicated a large improvement.

Around 75% of the respondents indicated an increase in income since the construction of the road, with 26% mentioning a large improvement. Around 43% and 35% respondents replied that their housing or household assets have improved. Among the number of businesses, 29% were established after the construction of the roads, which is a significant share, especially since construction some of the roads has been completed only recently. Of special interest was the involvement of the local people in the construction of the block and rigid pavements. Around one-thirds of the respondents using the block roads were involved either during construction or maintenance of the roads, whereas the share is one-fourths for the rigid pavement users. This indicates that block roads possibly employ more local people, which is expected because of its LCS type of project delivery.

Overall, the survey results from all households show that the newly constructed rural roads, rigid or block, had large benefits to the society.

7.2.3 Based of Geotechnical Study

A three dimensional Finite Element (FE) analysis was carried out with six various block sizes. The results of the parametric analysis show the effect of (1) block size, (2) block shape and (3) block depths on the applied load (bearing capacity) of those blocks. Results showed that the variation of applied load on vertical displacement for the block size and found that it does not have any lasting effect. The same result is observed for the case of block shape analysis result. This variation is pronounced only in the case of very thin block. Due to the thin formation of the block, its load-displacement curves vary a lot along the middle section, indicating the possibility of uneven settlement in course of time. From the analysis it was clear that the effect of size of the block is highly pronounced. The effect of block shape and block depth are not so pronounced although theoretically there are effects of block shape and block depth, but considering the conservativeness of this analysis, these effects can be safely ignored. From the three dimensional analysis it has been found that the road section can carry much higher load. It can marginally carry the LGED designated load (8.2 ton) for rural roads.

One of the objectives of this analysis was to improve the riding quality of the block-paved roads at Sunamganj. It can be improved by designing the blocks with a particular side sloped. A Finite Element parametric study is conducted on the effect of side slope of the blocks on the bearing capacity of the block. From the 2D analysis it was obvious that the bearing capacity increases exponentially with the increase in slopes of the sides of the blocks. But with the increase in slope of the block, its vulnerability of breakage will also increase. So it will need some field trial, before deciding a particular slope.

The block settlement analysis revealed that the actual load on the block pavement is far below the smallest block. So the bearing capacity of the current block is underutilized.

From the discussion of the analysis of the results, it is clear that size of the blocks has the most prominent effect on the bearing capacity and settlement of the block. Increase in block size will increase the bearing capacity, reduce the settlement and hence increase the riding quality to some extent. But the increase in weight will create distress among the labor. The current size of the block is just right in size. However, block size can be increased by reducing the depth to keep the weight good for LCS by using the design graph. Riding quality can be improved by increasing the side slope of the block, but it needs field trial before a particular side slope is approved.

7.2.4 Based of Road Safety Study

Field observation revealed that the average speed of motor cycle on rigid pavement road is about 38 kmph as compared to 23 kmph on block pavement road with similar road-traffic (geometric and operational) and environmental conditions, which clearly demonstrated that the block pavement road has the potential to arrest speed of vehicles. It was also observed that block pavement road has good safety record as compared to that of rigid pavement road. Considering the fact that village road has high degree of exposures due to the presence of heterogeneous traffic, lots of non-standard vehicles, drivers with no training and license and most importantly due to the presence of large number of vulnerable pedestrians, safety must be given utmost priority in providing connectivity in rural area. That is why in planning and designing safer village road, as a first step the block pavement should be given preference over rigid pavement to make the road self enforcing in reducing speed and thereby to make safety as a built-in feature of the road. Moreover, the block pavement road could gainfully be used at the hazardous locations like driveways connecting road adjacent houses without any setback, bends, junctions, etc. as a speed reducer or calming device.

7.3 Recommendations

Considering the fact that the labor intensive LCS based infrastructure development project is sensitive to quality control and observing the lack of supervision in mixing ingredients, making blocks and curing work, it is suggested that job center based (JCB) concrete block manufacturing system could be a better option. Alternatively, quality of concrete blocks could be improved by introducing mixture machine or compressed block manufacturing technique.

To overcome the problem related to shortage of mould which often causes disfigured and irregular shape of blocks due to untimely drawn from the mould by the LCS workers, use of relatively quick setting cement in the concrete mixture could be a plausible solution.

It was also observed that due to scarcity of highland in the study area, prepared bocks are kept in stack with high height which in turn affects uniform level of curing, particularly when it is done with less amount of water. This curing related problem can be addressed by using a special admixture which has the potential to make curing less concrete.

Traffic control devices like road signs and marking which have the potential to control vehicular movements are found to be totally missing in the study area particularly at the hazardous locations. In order to improve safety situation, road signs and marking should be installed liberally.

Towards developing safer road in the rural fabric - strategies should be as follows:

- Instead of straight alignment curvilinear alignment i.e. a good blend of straight and curved segments should be adopted
- As far as possible sharp bend should be avoided
- All through road should not be built with good quality surface
- Combination of rigid and block pavement road would be the best hybrid system; where road environment would be compatible with relatively higher traffic speed building rigid pavement can be given preference over block pavement
- On the other hand, due to rough texture as the block pavement road has the potential to reduce speed as well as skidding problem of motor cycle, it should be used particularly at the sharp bend, driveways, shops and in between long straight segment of road to arrest over speeding of vehicles.

Other suggestions made by the respondents were :

- Widen of existing roads
- Enhance the network for better connectivity (to other major roads, rivers, markets, marshes)
- Make surfaces smoother (block to rigid, rigid to bitumen)
- Elevate the roads
- Pave the unpaved parts
- Maintain regularly
- Plant trees along the roads

Considering the overall performance and special submersible attribute of the block pavement roads, this type of road can also be gainfully use in the coastal regions as an adaptation measure against rising sea levels and frequent flooding due to climate change in other developing countries.