Technical Design Manual and Specifications for Utilizing Local Base Materials

Product 0-5562-P1

Research Project 0-5562

Conducted for

Texas Department of Transportation
P.O. Box 5080
Austin, Texas 78763

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Center for Transportation Infrastructure Systems
The University of Texas at El Paso
El Paso, TX 79968
(915) 747-6925

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by

Biraj Gautam, MSCE
Deren Yuan, PhD
Imad Abdallah, MSCE
and
Soheil Nazarian, PhD, PE

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Guidelines for Using Local Materials for Roadway Base and Subbase

Conducted for
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in cooperation with the Federal Highway Administration

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The University of Texas at El Paso
El Paso, TX 79968-0516

The University of Texas at Arlington
Arlington, TX 76019

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Biraj Gautam, MSCE
Deren Yuan, PhD
Imad Abdallah, MSCE
Soheil Nazarian, PhD, PE (69263)

Guidelines and Test Protocols for Using Local Materials for Flex Base or Subbase

Prior to using this guide and test, Research Report 5562-1 entitled "Guidelines for Using Local Materials for Roadway Base and Subbase," should be consulted. The user should verify all details, procedures, treatment level and their suitability for use on a given project.

The requirements for Grade 1 base materials by TxDOT Item 247 are proposed as the basis of evaluating and using local pit materials for roadway base and subbase. However, the Grade 1 requirements can be modified if desired to accommodate the local practice. The flow chart of activities is shown in Figure 1 and detailed step by step in the following paragraphs. Two strategies are proposed for improving the out-of-specification local bases: (1) Improving Gradation and (2) Chemical Treatment with Calcium-based Additives (limited to 2% for economical reasons).

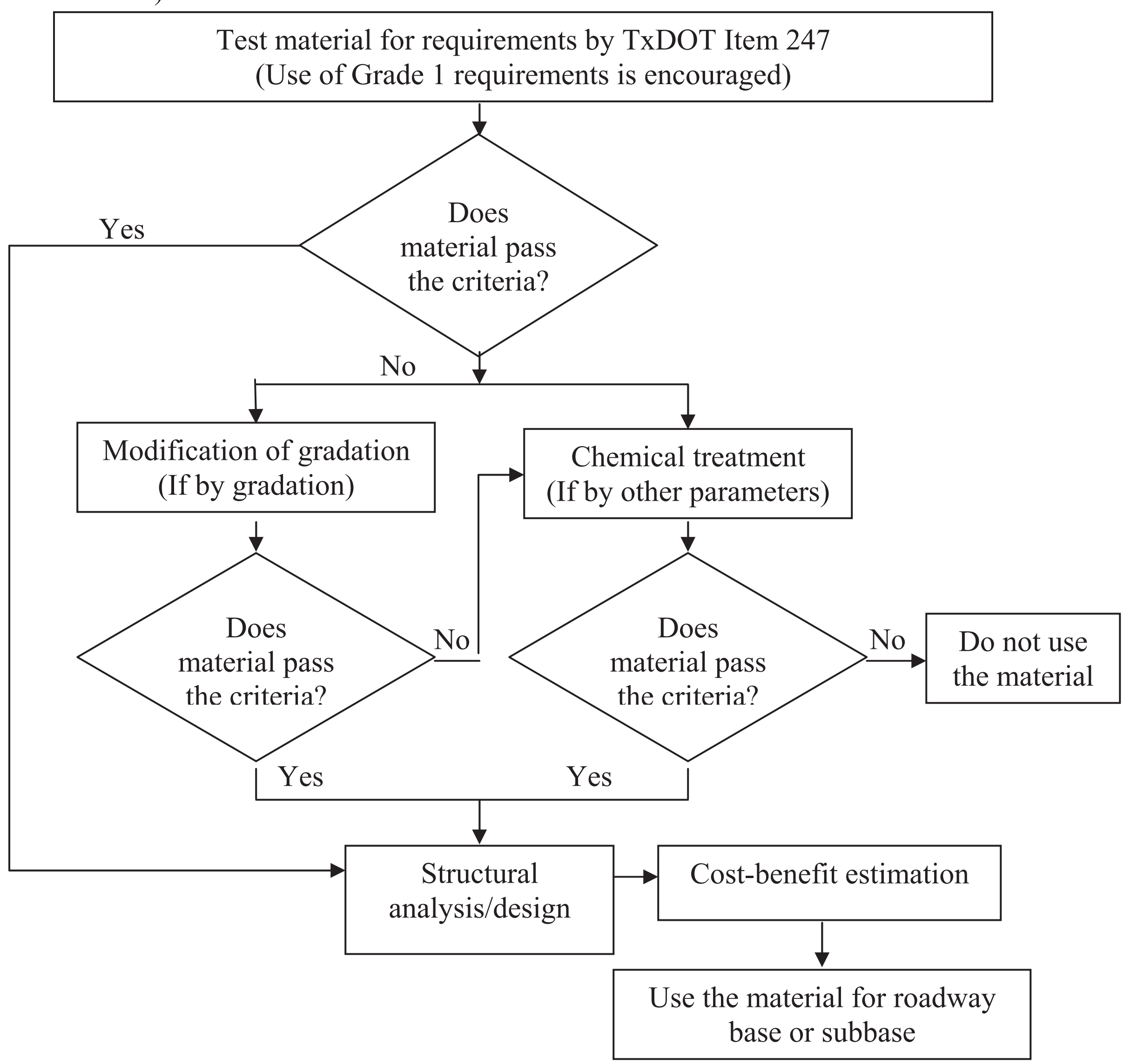

Figure 1- Flow Chart of Test and Evaluation Protocols

1. Sieve Analysis

The sieve analysis is carried out as per Tex-110-E except that a No. 200 sieve should be added to the sieve stack. *It is encouraged that the gradation curve be compared to the Item 247 Grade 1 requirements.*

If the gradation is slightly or partially out of Item 247 limits, particularly, for No. 40 sieve, the modification of gradation may be an option. Also if more than 15% of the material is finer than No. 200, the modification of gradation may be considered.

2. Atterberg Limits

Liquid Limit (LL) and Plastic Limit (PL) of material sample are tested as per Tex 104-E and Tex-105-E. Plasticity Index (PI) of the material is calculated as per Tex-106-E.

The LL should be less than 35 and the PI should be less than 10. If LL or PI or both are out of these limits, chemical treatment is recommended.

3. Moisture-Density

Moisture-density (MD) test is carried out as per Tex-113-E to obtain the optimum moisture content and the maximum dry density.

Optional Step: To estimate the variations in strength with moisture, the specimens prepared for developing the MD curves can be cured for 24 hours and subjected to unconfined compressive strength (UCS) testing as per Tex-117-E. If the UCS at optimum is less than the limits set for strength at 0 psi lateral pressure, treatment is recommended.

4. Strength

Testing for compressive strength of a specimen should conform to procedure Tex-117-E. Strength testing as per proposed Tex-143 is optional.

If one of the strengths at 0 and 15 psi lateral pressures as per Tex-117-E does not meet the requirement of Item 247, chemical treatment is recommended.

5. Moisture Susceptibility

The retained strength defined as the ratio of the strength obtained from zero lateral pressure after moisture conditioning as per Tex-117-E and strength at zero lateral pressure after 24 hrs of curing at room temperature (similar to Tex-143) should be the primary parameter for assessing the moisture susceptibility.

The retained unconfined compressive strength should be greater than 80%. If the retained strength is less than 80%, chemical treatment is recommended.

Tube Suction Test (TST) as per Tex-144-E is recommended for secondary assessing the moisture susceptibility of *untreated* material through dielectric constant measurement.

If dielectric constant is greater than 16, chemical treatment is recommended, depending upon the strength values as per Tex 117-E.

6. Resilient Modulus and Permanent Deformation

In order to ensure the performance of the local base, the resilient modulus and permanent deformation tests should be mandatory. Depending on the availability of the equipment, these tests should be carried out in-house or should be performed by a commercial laboratory. These values are required for structural analysis. The additional cost associated with this task is justified to ensure that the local base will not experience excessive permanent deformation. The resilient modulus test should be performed as per AASHTO T-307.

A representative[1] *resilient modulus greater than 40 ksi is recommended.*

The modulus test can be performed with a free-free resonant column (FFRC) device as per Tex-149-E as a preliminary estimate.

A seismic modulus of at least 80 ksi is proposed at this time.

The permanent deformation should be conducted as per NCHRP 1-29.

The primary reason for conducting the permanent deformation tests is to obtain parameters needed for assessing the rutting of the base as discussed in Report 0-5562-1. As such it is difficult to set acceptable limits. Usually, permanent deformation in excess of 2% may be considered excessive without structural analysis as discussed in Step 8.

7a. Chemical Treatment

Determine the type and amount of additives as discussed below. Repeat Steps 3 through 6.

a) Type of Additive - The decision tree (see Figure 2) for selecting the appropriate types of additive as per current TxDOT guidelines (Guidelines for Modification and Stabilization of Soils and Base for Use in Pavement Structures, 2005) should be followed. The two main factors considered are the percentage of material passing the No. 200 sieve and the Plasticity Index (PI). If the PI is greater than 10 by a large margin, the use of lime is recommended.

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[1] Representative modulus is estimated at a confining pressure and a deviatoric stress representative of the middle of the base layer due to an 18-kip equivalent single axle load. The typical values of the confining pressure and deviatoric stress of 15 psi and 15 psi, are recommended for a typical base.

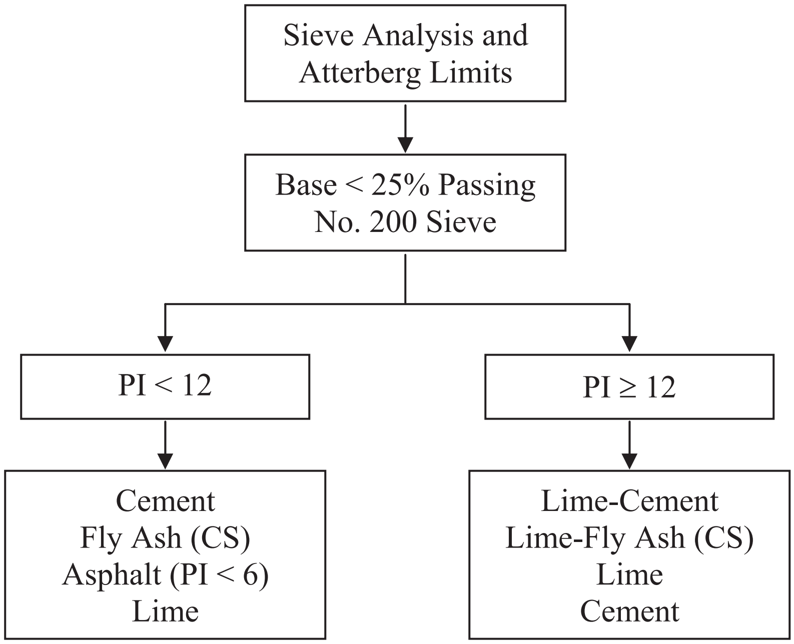


Figure 2- Decision Tree for Additive Selection

b) Amount of Additive – For economical reasons, the percentage of additive should not exceed 2% by dry weight of the material being tested. Since the amount of additives used is small, the strength parameters of the treated materials should be obtained as per Tex-117-E (instead of Tex-120-E or Tex-121-E or Tex-127-E) with specified limits reflected in Item 247.

If the treated material does not satisfy the strength requirements of Item 247, the use of greater amount of additives can be considered, if deemed economical. In that case, procedures Tex-120-E, Tex- 121-E or Tex-127-E may be conducted depending on the type of additives used.

7b. Modification of Gradation

Based on the result of sieve analysis in Step 1, the gradation of the material should be changed so that it would conform to the requirements of Item 247. If the percent passing No. 200 is substantially more than 12%, consider reducing the fine content of the mix.

The viability of the new gradation should be evaluated following Steps 3 to 6 above.

8. Structure Evaluation

The thickness requirements for the base course with the local materials should be carefully evaluated to ensure that the base layer is stable in terms of rutting. As documented in Report 0-5562-1, the current TxDOT design procedures (i.e. FPS19 or Texas Triaxial method) not only do not address this mode of failure, they provide thicknesses that may further aggravate it. Two other software packages that can address this mode of failure are available. Either VESYS (available from TTI) or IntPave (available from UTEP) should be used for this purpose. In the absence of these programs, an approximate method is proposed in Report 0-5562-1 that can be used as a preliminary check.

These programs require inputs that can only be obtained utilizing the Permanent Deformation tests discussed in Step 6. The use of presumptive values for the required parameters is strongly discouraged.

9. Cost Analysis

The cost of additional processing and construction steps of the local bases (either through change in gradation or chemical treatment) should be compared with the additional cost of the transportation of the high-quality bases. Due to the extremely volatile costs of construction materials and fuel, it would be difficult to provide rigid guidelines.

A worksheet, specifically developed for this purpose (see Appendix A for its user manual), can be used to determine the cost effectiveness of the use of local bases.

10. Use of Local Materials as Subbase

For bases thinner than 12 in., the use of the local materials without appropriate modification is not prudent. If the base is thicker than 12 in., the structural and economical feasibility of using the local material as is as a subbase should be explored. Structural analysis as part of this research indicates that most of the base rutting occurs in the top 7 in. of the base, and that a subbase layer with local materials between the base and subgrade do not significantly impact the performance of the pavement.

Appendix A
Cost Evaluation Tool Manual

Introduction

The Cost Evaluation Tool was developed in Microsoft Excel in order to understand the savings between the costs of construction using local materials and hauled-in/high-quality materials, especially when treatment or modification of gradation is involved. In order to estimate the cost of construction using high-quality/hauled-in materials and treated or untreated local materials, several associated costs such as material cost, construction cost and transportation cost are considered. A detailed discussion about the use of the program is presented in this tool manual.

Program Description

The Cost Evaluation Tool is composed of two Excel worksheets: 1) 'Input and Output' sheet and 2) 'Calculation' sheet. In the 'Input and Output' sheet, necessary inputs such as the dimensions of the pavement section, the base layer information and the cost information are provided. With the information provided as input, the program calculates the cost of construction using high quality base and local base materials. Finally, results in terms of cost comparison between the use of two different base materials, high quality and local base, are shown in the same excel sheet.

In the Calculation sheet, necessary calculations are shown in order to evaluate the cost of construction using high-quality and local base materials. Figure A.1 shows a cost evaluation program developed in Excel.

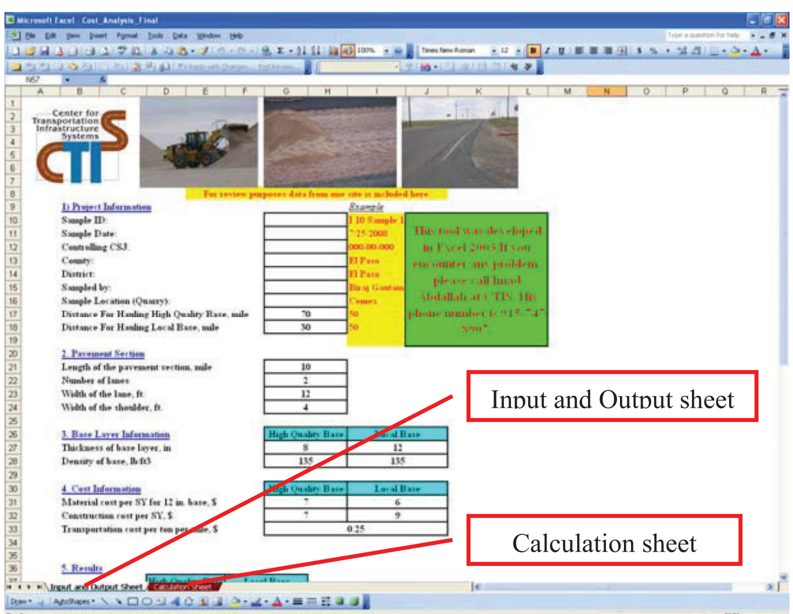


Figure A.1- Outlook of Cost Evaluation Program

Section 1: Project Information

Section 1 (Project Information) is mainly for the documentation of the site. Figure A.2 shows an example of the Project Information Section. The project information, such as Sample ID, Sample Date, Controlling CSJ, County, District, Sampled by and Sample Location may be provided. Also, the average distances to haul in high-quality base and local base materials should be entered. It is generally assumed that the distance for high-quality base materials is more than that for local base materials.

1) Project Information	
Sample ID:	
Sample Date:	
Controlling CSJ:	
County:	
District:	
Sampled by:	
Sample Location (Quarry):	
Distance For Hauling High Quality Base, mile	70
Distance For Hauling Local Base, mile	30

Figure A.2- Project Information

Section 2: Pavement Section

In this section, the dimensions of the proposed pavement sections are input. Figure A.3 shows an example of Section 2 with a typical example. The length of pavement section, the number of lanes, the width of the lane, and the width of the shoulders should be entered.

2. Pavement Section	
Length of the pavement section, mile	10
Number of lanes	2
Width of the lane, ft.	12
Width of the shoulder, ft.	4

Figure A.3- Pavement Section

Section 3: Base Layer Information

In this section, the information about base layer is provided. Figure A.4 shows an example of Section 3 with a typical example. The base thickness of the proposed section constructed with the high-quality base and local base materials along with their densities are entered.

3. Base Layer Information	High Quality Base	Local Base
Thickness of base layer, in	8	12
Density of base, lb/ft3	135	135

Figure A.4- Base Layer Information

Section 4: Cost Information

In this section, the information about several associated costs such as material costs, construction costs and transportation costs is input. This information is used to estimate the total cost of construction using high-quality base materials and local base materials. Figure A.4 shows an example of Section 4 with a typical example. The material cost per SY for 12 in. thick base layer for both types of material, high-quality and local base, are entered. It is generally assumed that the material cost for high-quality base is more than that for local base.

The second portion of this section requires the construction cost per SY. The construction cost includes the equipment cost, the labor cost and the cost of chemical additives. It is assumed that the local base materials are generally of low quality and the hauled-in base materials are generally of high quality. The low-quality/local base material generally requires treatment to comply with the Item 247 requirements, whereas the high-quality/hauled-in base material, for most of the cases, does not require chemical treatment. Considering this fact, it is assumed that the construction cost for low-quality/local base material is more than the construction cost for high-quality/hauled-in base material.

The last portion of this section requires transportation cost per ton per mile. Although, the rate of transportation cost for both types of base materials, high quality and local base, is the same, it is generally assumed that the total transportation cost for high-quality base is more than the total transportation cost for local base materials, as the hauling distance for high-quality base material is greater than the hauling distance for local base material.

4. Cost Information	High Quality Base	Local Base
Material cost per SY for 12 in. base, $	7	6
Construction cost per SY, $	7	9
Transportation cost per ton per mile, $	0.25	

Figure A.5- Cost Information

Section 5: Results

In this section, results in terms of total cost saving using high-quality base and local base materials are shown. This result is based on the inputs provided from Section 1 through Section 4. Figure A.6 shows an example of Section 5 with a typical example.

Also, to obtain allowable distance that can be traveled to haul in high-quality base material to realize potential cost savings, a graph between the cost saving using local base material in y axis and the difference in distance between the high-quality base material and the local base material in x axis is plotted. The distance where the cost saving is zero gives the additional distance that can be traveled to haul in high-quality base material.

5. Results

	High Quality Base	Local Base
Total Cost	$ 3,534,119	$ 3,685,267

Local base is 4% more expensive. Therefore, High Quality Base is more economical

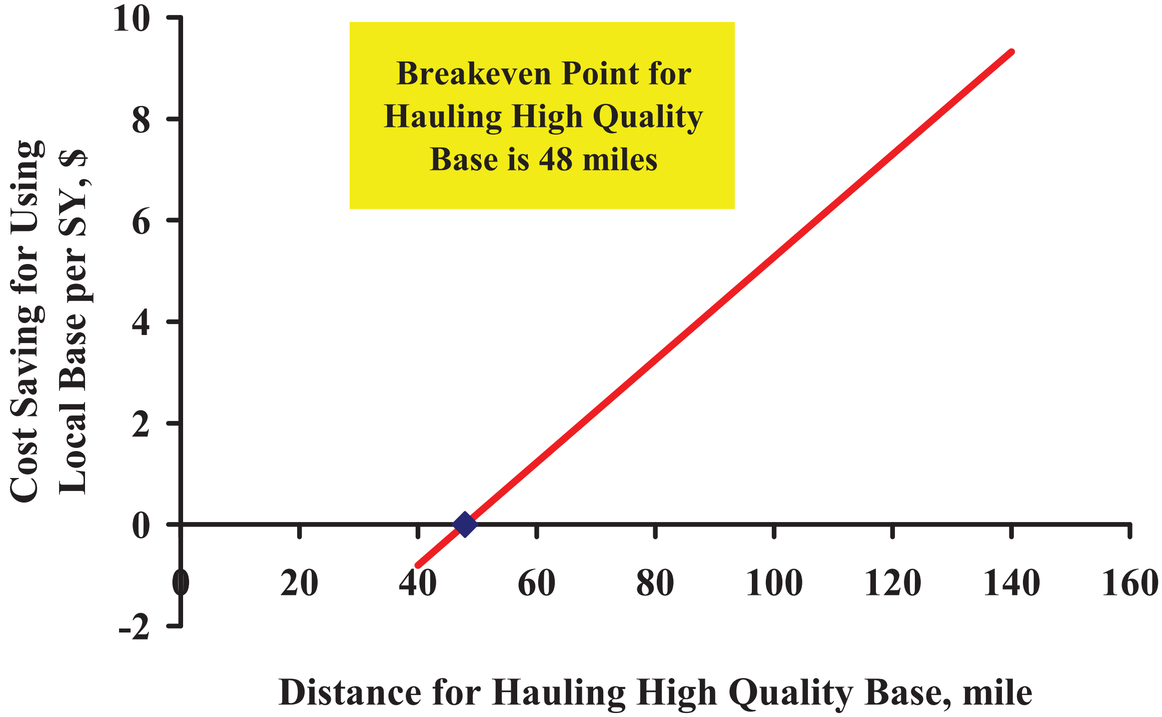


Figure A.6- Results of Cost Analysis

Section 6: Sample Calculation

<u>Input:</u>

Section 1: Project Information.

Distance for Hauling High Quality Base, mile = 70
Distance for Hauling Local Base, mile = 30

Section 2: Pavement Section.

Length of the pavement section, mile = 10
Number of lanes = 2
Width of the lane, ft = 12
Width of the shoulder, ft = 4

Section 3: Base Layer Information.

Base Layer Information	High Quality Base	Local Base
Thickness of base layer, in.	**8**	**12**
Density of base, pcf	**135**	**135**

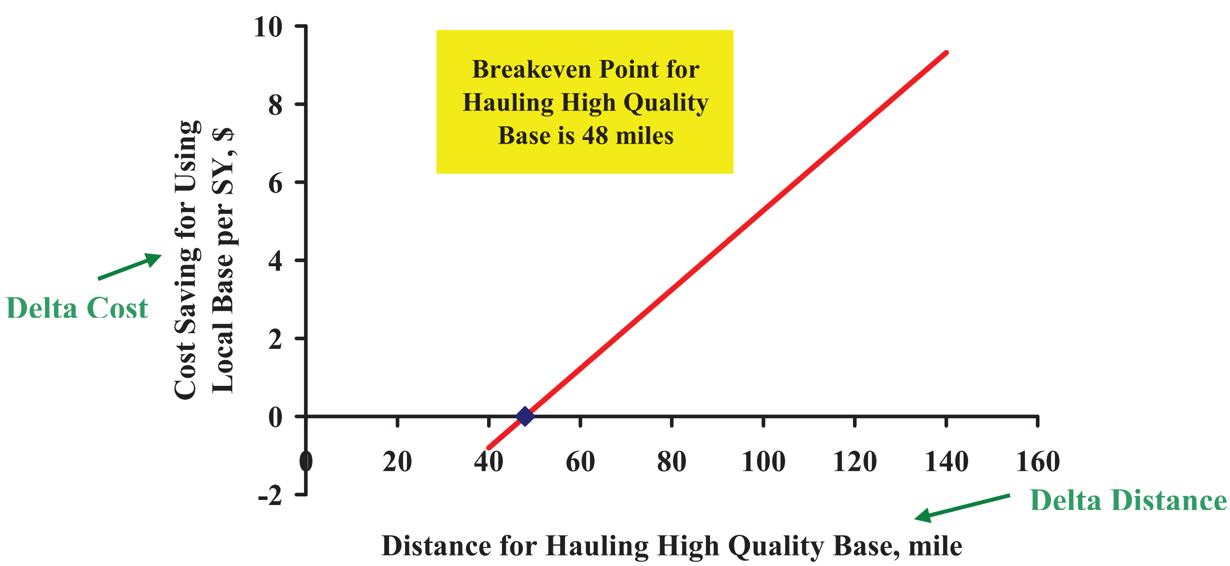
Section 4: Cost Information.

Cost Information	High Quality Base	Local Base
Material cost per SY for **12** in. base, $	**7**	**6**
Construction cost per SY, $	7	9
Transportation cost per ton per mile, $	**0.25**	

Calculation:

Base Layer Information	High Quality Base	Local Base
Material cost per SY,$	= (8/12) * 7 = 4.7	= (12/12) * 6 = 6
Transportation cost per mile per SY, $	= 0.25/(2000/(135*27*((8/12)/3))) = 0.101	= 0.25/(2000/(135*27*((12/12)/3))) = 0.152
Construction cost per SY, $	7	9

Delta Distance, mile	Delta Transportation Cost, $	Delta Cost (Total), $
(70 – 30) = 40	= 0.101*40+(0.101-0.152)*30 = 2.5	=(4.7-6)+(7-9)+2.5 = -0.8
45	3.0	-0.3
50	3.5	0.2
55	4.1	0.7
60	4.6	1.2
65	5.1	1.7
70	5.6	2.2
75	6.1	2.7
80	6.6	3.2
85	7.1	3.8
90	7.6	4.3
95	8.1	4.8
100	8.6	5.3
105	9.1	5.8
110	9.6	6.3
115	10.1	6.8
120	10.6	7.3
125	11.1	7.8
130	11.6	8.3
135	12.2	8.8
140	12.7	9.3



Cost	High Quality Base	Local Base
Transportation Cost per SY, $	= 0.101*70 = 7.1	= 0.152*30 = 4.6
Material Cost per SY, $	4.7	6.0
Construction Cost per SY, $	7.0	9.0
Total Cost per SY, $	**= 7.1+4.7+7.0 = 18.8**	**= 4.6+6.0+9.0 = 19.6**

Total area of the pavement section, SY = (2* 12+ 2* 4)*(10*5300)/9
= 188444

Output:

Section 5: Results.

Results	High Quality Base	Local Base
Total Cost, $	= 18.8 * 188444.44 = 3,534,119	= 19.6 * 1884444.44 =3,685,267

Hence,

Local base is (3,685,267/3,534,119-1) *100 = 4% more expensive. Therefore, High Quality Base is more economical.