

# A knowledge-based database on municipal waste in road construction applications

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**ABSTRACT** - *Municipal Solid Wastes (MSW) are generated /available in huge quantities. Quite a large amount of solid rubbish is contributed by our households in the form of domestic wastes which constitute heaps of municipal refuse poses serious disposal problems. If these wastes are not properly disposed off, this can prove perilous and environmental hazard. Such places often become a home for rats, flies, bacteria, mosquitoes and a large number of vectors, having the potential of causing many human diseases. The damage to the environment by the uncontrolled disposal of solid wastes can be clearly seen. The waste is dumped in the streets awaiting transport to the disposal sites and into the river. The damage to the environment by the uncontrolled disposal of solid wastes can be clearly visualized.*

*Thus it is imperative for a large-scale utilization of MSW or Municipal Waste (MW) in the construction of roads. MSW information is available in the form of research papers, articles, reports etc. However such information is scattered and is not available at one place for the prospective users. Keeping the above in view, it is intended to develop MSW and Municipal Waste Combustor Ash (MWCA) (is the solid residue that remains after the combustion of municipal solid waste) information database which contain detail information in program description files. The program description file on MSW and MWCA provides the user with general information, detailed production and use, engineering and laboratory tests, and environmental information. Developed database is useful in road construction, as well as recommendations for monitoring field trials and also to make the same available to the user at one place which will be Window based and can be used very easily and conveniently.*

**Index terms-** *Application, engineering properties, program description screens specification, and VISUAL BASIC 6.0.*

## 1. INTRODUCTION

During the last few decades rapid growth of population, industrialization and urbanization have resulted in increase in environmental pollution in the form of wastes. Wastes are unwanted residual materials, which cannot be discharged directly or before suitable treatment, to the atmosphere or to any receiving site. The solids, semi-solid and some liquid wastes are matter of great concern and have to be utilized

suitably in different construction applications. Research is being carried out to utilize different solid wastes like fly ash from thermal power stations, steel slags from steel industries, hospital wastes, red mud from aluminum industries, quarry wastes etc. Research is also therefore required to be carried out regarding utility of municipal solid wastes, which are available in huge quantities. Quite a large amount of solid rubbish is contributed by households in the form of domestic wastes. Some of the constituents of these wastes are groceries food scraps, vegetable remains, packing materials, paper, remains of used coal, ash, wood, metals, plastics, ceramics, glass etc. If these wastes are not properly disposed off, this can prove perilous and environmental hazard, such places often become a home for rats, flies, bacteria, mosquitoes all having the potential of causing many human diseases. The damage to the environment by the uncontrolled disposal of solid wastes can be clearly visualized.

The generation of huge quantities of MSW poses serious disposal and environmental problems. Thus it is imperative for a large-scale utilization of MSW and is bulk utilized in the construction of roads.

Extensive research work has also been done in India as well as abroad and the studies have shown that MSW has a great potential for its use in road works. However, it is not utilized properly on our roads mainly due to lack of information on the subject. As a result million of tons of MW are getting accumulated and causing serious environmental problems.

At the present time most operating facilities in the U.S. recover the ferrous metal fraction present in municipal waste combustor ash, which can comprise approximately 10 to 20 percent of the total ash fraction. Only a very small fraction (less than 10 percent) of the non-ferrous fraction of the ash generated in the U.S. is recovered and utilized. Most of this fraction is used in landfill cover applications. A small unknown fraction is used as an aggregate substitute in road base applications. MWCA has been used as a granular base in road construction, as a fill material, and as an embankment material in Europe for almost two decades. Municipal waste combustor ash has also been tested for use as an aggregate substitute in asphalt paving mixes, where it has performed in a satisfactory manner, particularly in base or binder course applications. In this application, the ash is used to replace the sand-size or fine aggregate portion of the mix. There are presently no known commercial uses of municipal waste combustor ash in this application.

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In India on a number of road projects, municipal waste (MW) and marginal material have been used and data is available in the form of research papers, articles, reports etc. However such information is scattered and is not available at one place. Keeping the above in view, it is intended to develop database on MW and MWCA which contain information for the use of above in highway/geotechnical engineering application.

The aim of developing the proposed database on MW is to recommend for laboratory engineering tests that can be used to assess the suitability of MW for use in geotechnical - related applications, as well as recommendations for monitoring field trials and also to make the same available to the user at one place which will be Window based and can be used very easily and conveniently. The database would provide the user with both general and detailed engineering and environmental information on MW. Database contains two program description files which provide brief description of the above with text, photographs and tables.

### II DEVELOPMENT OF DATABASE

The CRRI Municipal Waste Material Information Database Use in Highway/Geotechnical Engineering Related Applications is a Windows-based program containing detailed information on municipal waste. This paper assumes the user is familiar with the Windows environment. This section provides a general overview of the program, system requirements, and installation requirements.. Included in the database are recommended laboratory engineering tests that can be used to assess the suitability of each MW for use in highway/geotechnical engineering related applications, as well as recommendations for monitoring MW field trials.

The database also includes a set of tools that provides the user with the means to edit the text within the database and update the information with new tables and maps to respond to new data inputs.

The database is divided into eight major categories that are intended to provide the user with both general and detailed engineering and environmental information on MW The eight major program categories are as follows:

*General Information:* A brief description and photograph of MW included in the database, a conceptual presentation and description of its production process, and a delineation of potential uses.

*Production and Uses:* A pictorial representation of the geographical distribution of production and use rates in the India and a listing of reported international uses for MW Included in the database.

*Engineering Properties & Laboratory Testing:* A description and tabular listing of the physical, chemical and mechanical properties of MW included in the database, and a listing and description of recommended laboratory testing methods to evaluate potential uses for MW included in the database.

*Environmental Properties:* A description and tabular listings of entire information shall be covered the trace metal, trace

organic, and leaching properties of each WRM included in the database, as well as a summary of key environmental issues.

*Applications:* A description of the design, construction, performance and research issues associated with the use of each WRM included in the database in a specified Highway/Geo-technical Engineering related Application, and a listing of reported state DOT specification.

*Field Testing:* A listing and description of recommended field-monitoring methods to evaluate field trials of each WRM included in the database.

*References:* A listing of references that were used to develop database.

*Contacts:* A listing of government and private agencies that can be contacted to get additional information.

Information on MW for the above eight categories can be incorporated in the program files. The developed database provides the information to Users, but it is not possible for users to edit the text and update with new tables and maps within the database to respond to new data inputs.

The newly developed database contains PASSWORD, so that it is not possible for users to copy the information which is stored in CD.

The database contains a pictorial presentation of the geographical distribution of production and use rates and engineering properties which describe the tabular listings of the physical, chemical and mechanical properties of each waste material. It also includes environmental properties which describe a tabular listing of the trace metal and organic properties of MW It describes the application of the design, construction, performance and research issues associated with the use of each MW. A listing and description of recommended laboratory testing and field monitoring methods of MW is included in the database. Finally listing of the references will be included in the development of the database.

*System Requirements:* Visual Basic 6.0 is used to develop MW information database. Create individual MW program files for nine categories such as General Information, Production use, Engineering Properties, Environmental Properties, Application, Laboratory Testing, Field Testing References and Contacts to get the additional information.

To create Municipal Waste database the required entire information shall be covered under the following broad categories:

- Getting information about Percentage use/Production/Loss of MW in International and National level
- Re-utilize the MW in road and embankment construction
- Provide pollution-free environment.
- Provide user both general and detailed engineering, environmental information
- Provide user Information about MW-

- ✓ Appearance
- ✓ Mechanical Property
- ✓ Physical Property

- ✓ Leachete Property
- ✓ Chemical Property
- ✓ Tests Applied on etc.

## 2.1 Program Description

This introductory section provides a general overview of the i) program and ii) system requirements.

### i) Program:

The MW Information database for use in road construction applications is a Window based program. This paper assumes that the user is familiar with the Windows environment. The database is intended to provide the user with both general and detailed engineering and environmental information on MW. To develop the database VISUAL BASIC 6.0 is used which provides the flexibility to edit and update the database to respond to new data inputs and also helpful to user to handle the project easily.

The developed database provides the information to Users, but it is not possible for users to edit the text and update with new tables and maps within the database to respond to new data inputs.

### ii) System Requirements:

Information on MW is collected from the division, journals, private agencies and government and sorted out the needful information accordingly to develop the database. It is required to create program description file which contains the tab of MW. Create individual program files for six categories such as General Information, Production and Use, Engineering Properties, Environmental Properties and Laboratory Testing, Application and Field Trials.

Information on MW can be incorporated in the above eight program files with the pictorial representation, description and tabular listings, description of the design, construction, performance and description of recommended laboratory testing and field monitoring methods.

## 2.2 Instructions for running the program

The following provides a detailed list of instructions for running the program.

i. *Starting the Program:* The below steps are followed to start the program:

- A. Click the windows Start button
- B. Click the Programs folder
- C. Click the MW Database folder.

The folder name may differ depending on the installation options.

### ii. Login Screen

After loading, when user clicks the Application in the Folder, it will ask for the User Name and Password as shown in Fig. 1. After entering the correct password it will display the MW Information Database Use in Highway/Geo-technical Engineering – Related Applications. The newly developed database contains PASSWORD, so that it is not possible for users to copy the information. The only original owner of the Database Application can change his/her Password after entering the correct License No.

### iii. Introduction Screen

The Introduction screen as shown in Fig. 2 will appear after the user login. When the introduction Screen appears, the program stops loading and waits for the user to choose one of the following five options:

- Program Description
- Continue
- References
- Acknowledgement
- End

## III. GENERAL PROGRAM SCREENS AND MAIN PROGRAM CONTROLS

The database contains a login screen, introduction screen, start screen and six major program categories screens. This section provides a description of start screen, main program controls and each of the six major program categories screens.

A. *Start Screen* After the Login Screen choose the program description, it will display the program description screen as shown in Fig. 3. After choosing continue, the MW Information Database Use in Geo-technical Engineering–Related Applications start screen appears with MW photograph and introduction text, illustrated in Fig.4.

B. *Main Program Controls* In the main program, six major information tabs along with the Main Program Controls appears. These Main Program Controls always remain visible and can be used to navigate the database, print information, add and edit data, get help, and exit the program. The Main Program Controls consist of a Menu Bar (on the top of the screen), a Toolbar (below the menu bar) and the six MW Information Buttons (located along the left side of the screen). the Menu Bar, and the six Information Buttons.

i. *Menu Bar:* The Menu Bar contains options for printing information, exiting the program, adding data, editing data, updating data, or getting help.

ii. *File:* The File Menu contains two options, Print and Exit. The Print option permits the user to print information on the currently selected MW.

iii. *Data:* The Data Menu contains two options, Edit Text and Add/Delete. The Edit Text and Add/Delete options perform the same functions as the User Tool's Add/Delete and Edit Text buttons located on the toolbar.

iv. *Help:* The Help Menu contains two options, Contents and About. The Contents Option loads in the Help File contents. The About option show the about box which allows the User the option to view Program Description Screen or Acknowledgment Screen again.

v. *Toolbar:* The toolbar contains two program controls: Selected MW and User Tools.

vi. *Selected MW:* This program control is provided by a drop-down list box that can used to select an alternative MW for which the user wishes to view information The drop-down list displays the name of the currently selected MW. To see a list of drop down MW in the database, the

arrow contained in the drop-down list box must be pressed. A list of materials will drop down. The list can be navigated by using the scroll bar adjacent to the list. The MW file will be selected by clicking the mouse on the desired materials. The database will then load in the information for the selected MW.

*Vii: User Tools:* The user Tools facility contains three program controls: Print, Add/ Delete, and Edit Text. The Print button performs the same function as the Print option in The Menu bar item File.

*viii. MW information buttons:* Pressing one of the six information buttons located on the left side of the screen brings up one of the CRR Database information screens. When a specific information button is pressed, the "light" next to that button turns off green while all other buttons remain red.

### C. Eight major program categories

Eight information buttons are located on the left side of the screen and each button brings up one of the database information screens. When a specific information button is pressed, the "light" next to that button turns off green while all other buttons remain red.

The database is divided into eight major categories that are intended to provide the user with both general and detailed engineering and environmental information, recommended laboratory engineering tests that can be used to assess the suitability of MW for use in highway/geotechnical engineering related applications, as well as recommendations for monitoring field trials are included in the database. The database also includes a set of tools that provides the user to edit the text within the database and update the information with new tables and maps to respond to new data inputs. The six major program categories in the form of Screens are as follows:

#### 3.1. General Information:

##### General Information Screen

The General Information Buttons can be selected to access the General Information Screen for the MW. The General Information Screen presents the User with a brief description and photograph of MW, a conceptual presentation and description of its potential process and potential uses. In the General Information Screen, three tabs are displayed:

- a. Material Description,
- b. Potential Uses and
- c. Production Process.

##### a. Material Description Tab

1) Material Description: Generally, the wastes of a municipality consist of sewage and solid refuse. The 'sewage' is the liquid made up of rainwater and the solids and fluid waste from houses, factories, industries, etc. The 'solid refuse' consists of solid wastes, street sweeping, rubbish, market refuse, ashes, rejected vegetables, food articles, animal waste matter, etc. Sources of the solid waste in a community are, in general, related to land use and zoning. Although any number of source classifications can be developed, the following categories are useful. Residential and Commercial-Residential and commercial solid wastes, excluding special and hazardous wastes, consist of the organic (combustible) and inorganic (noncombustible) solid waste from residential areas and

commercial establishments. Typically, the organic fraction of residential and commercial solid waste consists of materials such as animal and vegetable wastes (also called garbage), paper of all types, cardboard, and plastics of all types, textiles, and rubber, wood, and yard wastes. The inorganic fraction consists of items such as glass, crockery, tin canes, aluminium, ferrous metal and ashes. Special Wastes-Special wastes from residential and commercial sources include bulky items, consumer electronics, white goods, yard wastes that are collected separately batteries, oil and tires. These wastes are usually handled separately from other residential and commercial wastes. The principal sources of batteries and oil are from households, automobile and other moving vehicle servicing facilities. Hazardous wastes-Wastes or combinations of wastes that pose a substantial present or potential hazard to human health or living organisms have been defined as hazardous wastes. Institutional-Institutional sources of solid waste include government centers, schools, prisons and hospitals. Excluding manufacturing wastes from prisons and medical wastes from hospitals, the solid waste generated at these facilities are quite similar to residential and commercial solid waste generated at these facilities are quite similar to residential and commercial solid wastes. In most hospitals medical wastes are handled and processed separately from other solids. Construction and Demolition-Wastes from the construction, remodeling, and repairing of individual residences, commercial buildings, and other structures are classified as construction wastes. The composition is variable but may include dirt; stones, concrete, bricks, steel, plaster, lumber, shingles and plumbing heating and electrical parts. Municipal Services-Other community wastes, resulting from the operation and maintenance of municipal facilities and the provision of other municipal services, include street sweeping, road side litter, waste from municipal litter containers, landscape and tree trimmings, catch- basin debris, dead animals, and abandoned vehicles. Agricultural Wastes-Wastes and residues from diverse agricultural activities-such as the planting and harvesting of row, field, tree and vine crops; the production of milk; the production of animal for slaughter; and the operation of feedlots are collectively called agricultural wastes. Treatment Plant Wastes-The solid and semisolid wastes from water, wastewater, and industrial waste treatment facilities are termed treatment plant wastes. The sources of solids in a treatment plant vary according to the type of plant and its method of operation.

2) Municipal waste combustor ash (MWCA) is the solid residue that remains after the combustion of municipal solid waste. There are several ash streams that are produced in a modern municipal waste combustor. The two primary streams are bottom ash and fly ash. Bottom ash is the residue that remains in the primary combustion chamber and is typically quenched to suppress dusting. Fly ash is a fine, powdery material that is collected in the air pollution control systems of these combustors. In the U.S., municipal solid waste combustor ash is primarily managed (via disposal) as a combined (bottom and fly) ash stream. Approximately 8 million metric tons (9 million tons) of municipal solid waste combustor ash is generated each year in the United States. Unprocessed municipal waste combustor ash contains a

mixture of concrete blocks, bricks, ferrous and non-ferrous metals, glass, and fine mineral matter, with low levels of fine unburnt organics. After the ferrous metal and oversized plus 100 mm (4 in) materials are removed (wood, block, etc.) from either combined or bottom ash, the ash exhibits characteristics of a sandy-silty material is illustrated in Fig. 5.

#### b. Potential Use Tab

One of the means to overcome the disposal problem of municipal solid waste is to use its profitably. At present R&D work is being done in the areas as (a) Incineration of the garbage and power generation (b) Anaerobic digestion\bio-gas generation (c) composting (d) Fuel pellets. Bulk utilization of these wastes is possible only in roads and embankments. In this project an attempt is made to use processed municipal wastes in road construction especially in embankment and sub bases. If this is successful this will not only solve the disposal problem but could also alleviate problem of obtaining good quality aggregates for road works, and thus economizing the construction of roads.

Municipal waste combustor ash (grate ash) has been used as a granular base in road construction, as a fill material, and as an embankment material in Europe for almost two decades. (MWCA) has also been tested for use as an aggregate substitute in asphalt paving mixes, where it has performed in a satisfactory manner, particularly in base or binder course applications. In this application, the ash is used to replace the sand-size or fine aggregate portion of the mix. There are presently no known commercial uses of (MWCA) in this application. Bulk utilization is possible in the field of civil engineering applications especially construction of roads.

#### c. Production Process Tab

India Production: Municipal Solid Wastes are available in huge quantities. Quite a large amount of solid rubbish is contributed by our households in the form of domestic wastes. Some common examples are groceries, food scraps, vegetable remains, packing materials, paper, remains of used coal, ash, wood, metals, plastics, ceramics, grass etc. All these constitute heaps of municipal refuse. If these wastes are not properly disposed off, this can prove perilous and environmental hazard. Such places often become a home for rats, flies, bacteria, mosquitoes and a large number of vectors, having the potential of causing many human diseases. The damage to the environment by the uncontrolled disposal of solid wastes can be clearly seen. The waste is dumped in the streets awaiting transport to the disposal sites and into the river.

Urban wastes are an important source of supplying nutrients to the soil, if converted into compost. By composing city wastes, twin objectives are achieved:

(1) Garbage disposal and (2) Production of compost are a soil conditioner as well as a fertilizer. Compost when applied to soil increases the moisture retaining quality of the soil humus, besides supplying the essential micronutrients. Compost plants have already been set up in various parts of the country.

In most of the cities the method of composting is not so much successful as was expected due to the following reasons: -

- It has been observed that farmer is much reluctant to use compost in comparison to chemical fertilizer because of low percentage of valuable nitrogen.
- Even though pebble separator was installed to have a very fine end product, the compost was found to contain lot of impurities resulting in less demand of compost from the farmers.
- Pebbles that are separated out during composting were found to be of no use for the authorities and it again involved huge transportation cost to dump them in low lying areas.
- Production cost of compost was also much more than as expected. The decline in sale of compost is attributed to various factors like seasonal demands, drought conditions prevailing in the country etc.

### 3.2 Production and Use:

#### Production and Use Screen

The Production and Use Information Button can be selected to access the Production and Use Screen for the MW. The Production and Use Screen presents a pictorial representation of the geographical distribution of production and use data in India and a listing of reported international uses of MW. In the Production and Use Screen three tabs are displayed they are India Production, India Use Fig. 6 and International Use.

#### 1) India Production: -

Municipal Solid Wastes are available in huge quantities. Quite a large amount of solid rubbish is contributed by our households in the form of domestic wastes. Some common examples are groceries, food scraps, vegetable remains, packing materials, paper, remains of used coal, ash, wood, metals, plastics, ceramics, grass etc. All these constitute heaps of municipal refuse. If these wastes are not properly disposed off, this can prove perilous and environmental hazard. Such places often become a home for rats, flies, bacteria, mosquitoes and a large number of vectors, having the potential of causing many human diseases.

The damage to the environment by the uncontrolled disposal of solid wastes can be clearly seen. The waste is dumped in the streets awaiting transport to the disposal sites and into the river.

#### India Use: -

According to a report by the Asia Centre for Organization Research Development (ACORD), the quantity of waste that will be produced in the year 2021 is estimated to be between 17000 and 25000 tons per day. Even if it is possible to provide the maximum reduction of waste through composting and incineration, there might still be a minimum 20 % residue of 4000- 5000 tons per day that will have to be land filled in new sites. Waste from hospitals, industries, wholesale fish and scrap markets, and thermal power plants need specialized treatments. If not treated, these wastes get dumped in to the landfill sites and cost adverse environmental impacts.

India Production tab provides access to a map and text description highlighting MW production. The India Use tab provides access to a map and text description of data received from a national survey that summarizes the extent of use of the MW within each reporting state. The International Use tab

provides access to a table and text description describing the detail usage of MW internationally.

*U.S.A. Production-* Municipal waste combustor ash (MWC) is produced at approximately 120 waste-to-energy or solid waste reduction facilities in 30 states. The states, which produce the largest quantities of MWC ash, are indicated in red on the map and include Connecticut, Florida, Massachusetts, Minnesota, New Jersey, New York, Pennsylvania, and Virginia. States that produce somewhat lesser amounts of MWC ash are indicated in blue on the map and include California, Illinois, Indiana, Maine, Maryland, Michigan, Tennessee, and Washington. There are also 14 other states that produce comparatively lower quantities of MWC ash and these states are indicated in yellow on the map. States with no municipal waste combustion facilities are shown in white.

*U.S.A Use-* During the past 20 to 25 years, there have been a considerable number of efforts made to utilize municipal waste combustor (MWC) ash. MWC ash is presently being commercially used as an alternate to bidders in two states (Tennessee and Pennsylvania), indicated in purple on the map. States that have recently made concerted efforts to evaluate this material for use as a partial aggregate replacement in hot mix asphalt, as an aggregate for stabilized bases and granular bases, and as a potential embankment material are indicated in blue on the map and include Connecticut, Florida, Massachusetts, Minnesota, New Hampshire, New Jersey, and New York.

2) *International Use-* International use of municipal waste combustor (MWC) ash is summarized in the accompanying table. The Netherlands has made the most extensive use of MWC ash as an aggregate in either hot mix asphalt paving or cold mix surface treatments, and as an embankment material. Denmark has made general use of MWC ash as a granular base aggregate. MWC ash has also been used in the Republic of Germany as a road base material. There has also been limited use of MWC ash as an aggregate in hot mix asphalt paving, cold mix surface treatments, stabilized base, and granular base, as well as in flowable fill and as an embankment material.

### 3.3 Geotechnical Properties & Laboratory Testing:

#### Geotechnical Properties & Laboratory Testing Screen

Geotechnical Properties information button can be selected to access the Geotechnical Properties Screen for MW, Fig.7. Geotechnical Properties Screen presents a description and tabular listing of the physical, chemical and mechanical properties of MW. A listing and description of recommended laboratory testing methods to evaluate potential use is included in the database. In the Geotechnical Properties Screen three tabs are displayed which describes detailed information on MW in the form of three main properties. They are

i. Physical Properties ii. Chemical Properties and iii. Mechanical Properties

- Physical Properties
  - Water Absorption
  - Gradation
  - Particle Shape & Texture
  - Specific Gravity

#### Unit Weight

- Chemical Properties
  - Chemical Composition
  - Hydration Reactions
  - pH
- Mechanical Properties
  - Bearing Capacity
  - Permeability
  - Durability
  - Hardness
  - Particle Strengths
  - Shear Strengths
  - Thermal Properties

#### ENGINEERING PROPERTIES-

##### Physical Properties-

###### Absorption

Municipal waste combustor ash is highly absorptive with absorption values ranging from 5 to 17 percent for fine particles and from about 4 to 10 percent for coarse particles. Conventional aggregates typically exhibit absorption values of less than 2 percent. The accompanying table summarizes some reported water absorption values for municipal waste combustor bottom ash and combined ash for various size fractions.

###### Compacted Density

The compacted density of processed municipal waste combustor ash is in the range of 1280 to 1760 kg/cu m (80 to 110 lb/cu ft), which is somewhat lower than that of conventional aggregates. Maximum density has been reported at moisture contents in the range of 12 to 16 percent, by total weight. The accompanying table summarizes some reported compacted density data for municipal waste combustor bottom ash and combined ash.

###### Gradation

Screened minus 19 mm (3/4 in) municipal waste combustor (MWC) ash is a well-graded primarily sandy material. Approximately 60 percent of both bottom and combined ash falls into the category of a fine aggregate material. The measured silt content (minus 0.075 mm (No 200 sieve) fraction) of MWC ash can be expected to range from 5 to 15 percent. The accompanying table summarizes some gradation data for various size fractions of municipal waste combustor bottom ash and combined ash.

###### Moisture Content

The moisture content of municipal waste combustor ash can vary a great deal, ranging from approximately 20 to 70 percent on a dry weight basis. This relatively high moisture content is due to the quenching of the ash as it exits the municipal waste combustor. The accompanying table summarizes some reported moisture content data for municipal waste combustor bottom ash and combined ash.

###### Specific Gravity

Municipal waste combustor (MWC) ash is a relatively lightweight material compared to natural sands and aggregate. The bulk specific gravities reported range from 1.5 to 2.2 for

sand-size or fine particles and 1.9 to 2.4 for coarse particles, compared to approximately 2.6 to 2.8 for conventional aggregate materials. The accompanying table summarizes bulk specific gravity of MWC bottom ash and combined ash for various sieve size fractions.

**Unit Weight-** The unit weight of municipal waste combustor ash is relatively low compared to that of natural aggregate. The accompanying table summarizes reported unit weight data for municipal waste combustor bottom ash and combined ash.

**Grain size analysis:** Investigations have been undertaken to classify them from the point of view of their suitability for construction of embankments, sub grades, sub bases and wearing surfaces. Gradation and PI requirements for use in sub base/base courses are as shown. From the sieve analysis data the compost and mixed samples were classified as SM (silt sands) and pebble samples were classified as GW (well graded gravels with little fines). Data indicates that they are closely matching the requirements for use in sub bases.

#### *Atterberg limit tests:*

Sample is found to be non-plastic in nature, thus does not exhibit large changes in volume when subjected to changes in moisture content. This property is an essential requirement when it is used as an embankment material.

#### **Chemical Properties-**

##### *Chemical Composition*

The most abundant elements in combined ash are silica (Si), calcium (Ca), aluminum (Al), iron (Fe), sodium (Na), and potassium (K). Although ash composition can be expected to vary from facility to facility, these elements are present within predictable ranges. The accompanying table summarizes the range of major chemical constituents (metal oxides) that have been reported in municipal waste combustor bottom ash and combined ash.

**Free Aluminum-** Free aluminum present in municipal waste combustor ash can result in the formation of hydrogen gas when the aluminum is combined with water.

#### **PH**

The pH of municipal waste combustor bottom ash can be expected to be in the range of 8 to 9, that of combined ash (if lime is introduced in the air pollution control system) in the range of 10 to 12, and that of fly ash in a lime scrubbing system greater than 12.

#### **Salt Content**

The presence of calcium and other salts in relatively high concentrations in municipal waste combustor ash make the ash susceptible to hydration and/or cementitious reactions (particularly in combined ash which can contain unreacted lime) and subsequent swelling.

In addition, the high salt content also suggests that ash could be corrosive if placed in contact with metal structures, and that it would likely interfere with curing and strength development if used in Portland cement concrete.

#### *Mechanical Properties-*

##### *Bearing Strength*

California Bearing Ratio (CBR) values for municipal waste combustor ash reportedly range from approximately 75 to 150 percent. CBR test results for both bottom and combined ash are similar to those that could be anticipated for a well-graded crushed stone, suggesting excellent bearing capacity. The accompanying table summarizes reported California bearing ratio data for municipal waste combustor bottom ash and combined ash.

##### *Durability*

Municipal waste combustor ash exhibits good resistance to wetting and drying cycles as measured by the sodium soundness test. The accompanying table summarizes reported sodium sulfate soundness loss data for municipal waste combustor bottom ash or combined ash.

##### *Particle Strength*

Municipal waste combustor ash exhibits marginal particle strength when measured by the Los Angeles (L.A.) Abrasion test method. L.A. abrasion test loss values normally range from approximately 40 to 60 percent. The accompanying table summarizes the Los Angeles abrasion loss data for municipal waste combustor bottom ash and combined ash.

##### *Permeability*

Compacted bottom ash is a free-draining material, with coefficients of permeability ranging from E-02 to E-04 cm/sec). Compacted combined ash (particularly compacted combined ash with hydrated lime that is introduced into the ash through the air pollution control system) is a low permeability material with reported compacted coefficients of permeability ranging from E-05 to E-07 cm/sec.

##### *Shear Strength*

The apparent angularity of municipal waste combustor ash particles contribute to high shearing strength values as measured by the angle of internal friction. The accompanying table summarizes reported angle of internal friction data for municipal waste combustor bottom ash.

The chemical characteristics would indicate the method of stabilization that should be followed for the improvement of characteristics of municipal wastes. The result of chemical characterization tests for both grade A and grade C materials are indicated in tables given below. Results show that both grade A and C samples contain substantial amount of silica and alumina, which are an added advantage while stabilizing with cement or lime. Significant disadvantage with these materials was presence of high organic content. The amount of organic content in a material has to be reduced for the good performance of the embankment or sub-base. This can be achieved by mixing with local soil or inorganic material or by stabilizing with cement or lime.

#### *Mechanical Properties-*

##### *Standard Compaction Test:*

The purpose of a laboratory compaction test is to determine the proper amount of mixing water to be used, when compacting the soil in the field and the resulting degree

of denseness, which can be expected from compaction at optimum moisture content. To accomplish this, a laboratory test, which will give a degree of compaction comparable to, that obtained by the field method used is necessary. With a knowledge of the water density relation as determined by this test, better control of the field compaction of soil fill is possible because the OMC and the density which should be obtained are known by using this test procedure and these can be checked by field control tests. Maximum dry densities of pebble sample, compost sample and mixed sample found to be less than requirement for embankment soil compaction. To improve the material as a whole various stabilization techniques will be tried.

**CBR tests:** California bearing ratio test is a measure of shearing resistance of the material under controlled density and moisture conditions. IRC prescribe certain minimum required CBR values for the material to be used in sub bases.

According to IRC specifications for the material to be used in sub bases, up to traffic of 2 msa, CBR required is minimum of 20% and for traffic exceeding 2 msa, CBR requirement is 30%. For low trafficked roads like rural roads CBR can be relaxed to about 15%. From the CBR data obtained for municipal waste it is found that the samples have much less CBR than required. Adopting soil stabilization techniques can fulfill this requirement.

**Free swell index tests:** These tests are conducted to know the swelling nature of these samples. Free swell of these samples is only on an average 11%, which indicates that the sample is low, expansive in nature and doesn't require any detailed investigations.

**Strength tests:** Shear strength of soil is the resistance to deformation by continuous shear displacement of soil particles or on masses upon the action of shear stresses. All stability analysis in soil mechanics involves a basic knowledge of the shearing properties and shearing resistance of the soil.

The shearing resistance of a soil is constituted basically to the following components:

- The structural resistance to displacement of the soil because of the interlocking of the particles.
- The frictional resistance to translocation between the individual particles at their contact points and
- Cohesion or adhesion between the surfaces of the soil particles.

**Direct shear tests:** Direct shear test were conducted to determine shear strength parameters and to know the stress-strain behavior of these wastes. Strength parameters determined showed that the material behaves like granular material and thus achieve its strength from intergranular friction alone.

**Consolidation tests:** Consolidation tests were carried out for mixed samples to determine its compressibility characteristics as well as its time rate of consolidation, which will help in settlement calculations.

**Mechanical stabilization for construction of embankments:**

For embankment construction two proportions 70:30 and 50:50 i.e. with 30 and 50% of local soil were evaluated for their feasibility in the laboratory. Such mixing for improvement of engineering properties is termed as mechanical stabilization. The compaction and CBR test

results of these mixtures are shown in table. The proportion 50:50 satisfied the MOST specifications for embankment construction and from the shear box tests conducted on both these proportions, the proportions 50:50 is found to have better cohesion characteristics which is quite essential for erosion control when used for embankment construction. Hence because of these reasons the proportion (50:50) is chosen for embankment construction in the field. In order to find out the approximate proportions of municipal waste-soil combination or municipal waste-fly ash combination for lime/cement stabilization for use in sub-bases the method of blending by sieve analysis is adopted. This is the simplest and quicker method by which it is possible to improve the plastic properties and particle size distribution of the mixture. Proportioning has been done based on the grading requirements for materials to be used in sub-bases.

### *Environmental Properties Screen*

The Environmental Properties information button can be selected to access the Environmental Properties Screen for the selected W.M. The Environmental Properties Screen presents information on Trace Metals, Trace Organics, Leachate Properties, and Environmental Issues for the selected W.M.

Four tabs are displayed in the Environmental Properties Screen. They are:

Trace Metals, Trace Organics, Leachate Properties and Environmental issues.

Each tab provides User access to a text description of properties presented, and may be accompanied by a table summarizing each property for which data are available. In the Engineering Properties Screen, the User Tool Add/Delete is enabled, allowing the User to add or delete properties from the MW in the selected section.

The Laboratory Testing button can be selected to access the Laboratory Testing screen. The Laboratory Testing Screen presents a listing of recommended laboratory testing methods to evaluate in a chosen application. In the Laboratory Testing Screen two drop-down list boxes are displayed. Choose Application and choose Test Property boxes. The top drop-down list box provides the User to choose an application which can view information for the MW. The bottom drop-down list box provides the User to select a test property which will view information for MW and application. Once an application and test property is chosen, the User will access information that is presented on recommended test methods, comments regarding the test methods, and test criteria. Physical properties, Chemical properties and Mechanical properties of MW is summarizes in the database in detail with tables in three tabs.

### *3.4 Environmental Properties:*

#### *Environmental Properties Screen*

The Environmental Properties information button can be selected to access the Environmental Properties Screen. A description and tabular listings of the trace metals, trace organics, leaching properties and environmental Issues of MW included in the database, as well as a summary of key environmental issues and heavy elements and radionuclide in detail is provided in four tabs.

Each tab provides the User to access a text description of proposed test track and leveled. Water is then added at its properties presented and accompanied by a table summarizing optimum moisture content and compacted with 8-tonne roller each property for which data are available.

### 3.5 Applications:

#### Design-

Flexible pavement design was done in accordance with IRC: 37 – 1970 “Guidelines for the Design of Flexible Pavements”. In this method sub grade strength is assessed in terms of the CBR value of sub grade soil. Traffic is defined in terms of the cumulative number of standard axles to be carried during the design life of the road. As data is not available to adopt the equivalent axle load concept, the CBR method that considers traffic in terms of total number of commercial vehicles per day was used. As the design traffic is not more than 150 commercial vehicles per day, the thickness of different layers of sub-base, base and surfacing can be determined by repeated use of these curves and duly taking into account the minimum thickness and compositional requirements as per the modified design method of pavement design. As the requirements with regard to the minimum thickness and composition of various layers are in terms of cumulative number of standard axles, the following approximate traffic conversions may be used as given in Table to decide the minimum thickness and composition of various layers.

Ministry of Surface Transport (MOST) Specifications for Road and Bridge Works recommend compaction of subgrade soil to 100% of maximum dry density as per I.S. light compaction. The average laboratory CBR at 100% of MDD (I.S. light compaction) is found to be 9.5 percent. It has been observed that the CBR achieved at field during construction is normally somewhat lower than the CBR has been based on the design CBR of 7 percent. As the traffic expected after the construction is approximately about 100 commercial vehicles per day, design was made based on CBR curve C. Total thickness of the pavement was found to be 300 mm.

#### Construction-

##### Site selection

Based on the analysis of the results obtained it was concluded that the material could be tried in ODR/MDR or village roads. In order to explore the possibility of using solid municipal wastes in roads, Municipal Corporation of Delhi (MCD), the discussions with Chief Engineers and other officers, a few sites were identified for experimental sections. Visits were made to these sites for the preliminary investigations and based on these, it was decided to lay the test tracks with municipal wastes along “Nijampur to Trikrikala” road section. The samples of sub grade soil and other locally available materials were collected for developing specifications for the experimental test sections. However, due to some other problems finally the site was shifted to Garhi Randhala – Ladpur road section (length of 500m) near Garhi village for construction.

##### Construction of test section

The four design specifications for use in sub base layer of road pavement including conventional specifications followed by MCD were constructed by MCD under the supervision of CRRI. The existing kutchha road is cleaned of debris and the soil from the borrow area is laid along the

to its maximum dry density. The finished surface forms the sub grade. The loose layers of estimated thickness of processed municipal wastes/soil/fly ash/cement/ lime are then laid over the finished sub grade one above the other as per the designed specifications. All the three layers are then thoroughly mixed in dry condition with tractor bound Rotiller/Rotavator (developed by CRRI). The mixed material is then made into compartments and water is added on volume basis as per optimum moisture content requirements. Some time is allowed for the water to be absorbed by the mixture and then through mixing of wet mixtures is done with the same equipment. Compaction is then done with an 8 tonnes roller. Quality control test are done at each stage of construction. The base and the surface layers are then laid on the finished sub base layer as per IRC Standards.

#### Processing

The sub grade was prepared by removing all the vegetation and other extraneous matter, lightly sprinkled with water if necessary, and compacted maintaining proper camber with 8 to 10 tonnes smooth wheel roller to the specified dry density which is taken as 100% proctor density. In case the specified dry density was not achieved, the top 15 cm of earth was loosened, pulverized, and sprinkled with water to bring the moisture close to optimum moisture content, leveled to proper profile and camber, rolled to achieve 100% Proctor density.

#### Performance

The constructed test sections should be monitored for a certain period of time to arrive at proper conclusions. The programmes of performance evaluation include structural evaluation of constructed test sections by carrying out Benkelman beam deflection studies and the functional evaluation by dipstick based profile measurements. The first pavement performance observation was taken after the first monsoon period and the next two observations were taken over an interval of about 6 months.

#### Specification

##### Construction specifications

##### Specification 1.

Length of test section – 100 m

Width of test section – 3.5 m

Thickness – 320 mm

##### Materials

Processed municipal waste (PMW): This was collected from MCD compost plant at Okhala, New Delhi.

Soil: This was collected from identified borrow areas.

Cement: Fresh cement as per specification was used.

**Stone and other conventional materials:** for WBC etc. as per IRC specification was used.

Equipment: Rotavator (Rotiller), Road roller.

Laying and mixing of PMW-Soil-Cement (Sub-base)

The PMW, soil and cement were mixed in the proportion of 50:45:5 by weight. The quantities of these three materials were calculated for the proposed test specification (L=100 m, Width=3.5 m and compacted thickness of 12.5 cms). The PMW layer was spread over the entire length and

width of the test section in the required thickness using thickness blocks. Over PMW the soil that is properly pulverized was spread in desired thickness. The surface was then made into a grid structure and required quantity of cement is the added (percent by dry weight) in each grid. The cement was then spread uniformly over the entire road section. All the three layers of PMW, soil and cement were then mixed together using tractor bound rotavator/ rotillor and leveled. The tractor bound rotillor was run repeatedly till the materials were well mixed. This is called dry mixing. Again the surface was made into grid pattern and then required quantity of water was added (calculated based on optimum moisture content as determined in the laboratory). The wet mixing was again carried out again using rotillor till uniform mixture was achieved. After uniform mixing the material was spread again to proper profile and camber using camber plate. The moisture content on the mix was checked intermittently in the field so as to confirm that it lies between OMC  $\pm$  1.5%. Additional water if required has to be added and remixed by rotavator uniformly. If the moisture content is more the layer shall be loosened and allowed for drying for some time.

#### Manual method of mixing and laying

The proposed municipal waste is a heterogeneous material and the manual method of mixing if adopted shall be carried out with due care. The measured quantities of PMW shall be stacked properly on the shoulders. Measured quantity of soil and cement shall then be spread over PMW. This shall be then thoroughly mixed manually till a uniform mixing is achieved. Precautions shall be taken with proper hand gloves and gumboots during mixing. After this dry mixing the material shall be stacked with height not exceeding 45 cm. The surface shall then be divided into grid structure for addition of calculated quantity of water. Wet mixing shall be carried out to achieve uniform distribution of water. The mixed material shall then be spread uniformly along the alignment and then compacted to the designed thickness and profile. The time lag between mixing and compaction shall not be more than 3 hrs.

#### Compaction

After spreading the material, compaction was carried out with 8-10 tones power roller. The rolling was commenced from edges and progressed towards the central line with an overlapping of wheel by 50% each time. After reaching the central line, the compaction was started from the other edge and progressed towards the center. The compaction was continued until the density achieved was 100% of the maximum dry density. The field density was checked by sand replacement method according to BIS: 2720.

#### Curing

Sprinkling of water regularly for a minimum period of 7 days was done to cure the compacted sub-base. This was done manually or by using a water sprinkler.

#### Base course (WBM) 17.5 cm thick

Base course was constructed in two layers as per IRC specification.

#### Surface course

20 mm thick premix carpet was laid as IRC specification.

#### Specification 2.

Length of test section – 75 m  
Width of test section – 3.5 m  
Thickness – 320 m

Length, width and the materials used are the same as in specification 1. Except that the quantity of cement was increased in this specification. The ratio of the materials viz. Municipal waste, soil and cement was 70:22:8 respectively.

#### Specification 3.

Length of test section – 55 m  
Width of test section – 3.5 m  
Thickness – 320 m

#### Materials

##### Processed municipal waste-

MW was collected from MCD compost plant, Okhla.

##### Fly ash-

Fly ash was collected from nearby thermal power station.

##### Lime-

Commercial grade hydrated lime (packed in plastic bags was collected and stored at site. The calcium hydroxide content in the lime shall not be less than 70% as determined by Rapid Iodine method.)

##### Stone and other materials-

Required for WBM as per specifications was used.

#### Mixing

Processed municipal waste, fly ash and lime layer was spread uniformly in the ratio 70:22:8 respectively on the prepared sub grade in a quantity sufficient to achieve the recommended compacted thickness (12.5 cm) of stabilized layer. The material was laid in the calculated thickness and proportion by weight and mixed under slightly moist condition to prevent blowing of lime. The mixing was obtained.

#### Specification 4.

The test section was constructed as per conventional method and treated as control panel. The total thickness of the pavement in the test section was 250 mm excluding premix coating.

#### Environmental Issues

The municipal solid wastes arising from human activities have become one of the major environmental problems causing extensive pollution and threat to human health. Of late, the problem of solid waste disposal, both domestic and industrial, has become very acute in large metropolis of India because of the limited disposal facilities. It is reported that the average daily refuse generation in a metropolitan city like Delhi in India is approximately about 6000 tones. These huge quantities of wastes are dumped haphazardly in the streets or roadside locations awaiting transport to the disposal sites and into the rivers. It is necessary to use these municipal solid wastes profitably.

*Research-* Bulk utilization of these wastes is possible only in civil engineering works like construction of roads and embankments. Central Road Research Institute (CRRI) has carried out R&D work in using these 4 wastes in road sub bases and embankments. Test sections have been constructed

at Garhi Randhala-Ladpur road near Garhi village, Delhi, wherein stabilized municipal wastes were used in sub base layer of road pavement. The performances of these sections were monitored over a period of time and results have indicated that all the test sections constructed using municipal wastes are performing well even after three years.

*Applications Screen-* The Applications information button can be selected to access the Applications Screen. The Applications Screen presents specific information on design, specifications, processing Fig.8, construction Fig. 9, performance, and research. A description of the above six issues are associated with the use of MW included in the database separately for Asphalt Pavement, Embankment or Fill, Stabilized Base, Flow able Fill, Portland Cement Concrete are explained in a specified Highway/Geo-technical engineering related Application. In the Applications Screen six tabs are displayed they are design, specifications, processing, construction, performance and research. To obtain information from the Application Screen, the User must choose an application from the Choose Application drop-down box presented on each screen. Once the application is chosen the User can then select the desired tab to access information (text and tables) on design, specifications, processing, construction, and performance and research issues for the related application. In the Applications Screen when the User Tool Add/Delete is enabled, it will allow the User to add or delete an application.

### 3.6 Field Trials or Field Testing:

#### Field Testing Screen

The Field Testing button can be selected to access the Field Testing Screen. In the Field Testing Screen Fig.10 two drop-down boxes are displayed. The User must choose an application and test property from these drop-down boxes to view information. The first drop-down list box provides the User to choose an application to view information and the second drop-down list box provides the User to choose a property to view information. Field testing screen presents a listing and description of recommended field-monitoring methods to evaluate field trials of MW. Asphalt Pavement, Embankment or Fill, Stabilized Base, Flow able Fill, Portland Cement Concrete are explained in four tabs that provide the access to information on monitoring field trials for four types of monitoring activities, they are: a. Short Term Engineering, b. Long Term Engineering, c. Short Term Environment and d. Long Term Environmental issues.

The Short-Term Engineering and Short-Term Environmental tabs provide the User to access the recommended engineering and environmental monitoring methods respectively to assess MW performance during the production process as well as before, during, and after field construction.

The Long-Term Engineering and Long-Term Environmental tabs provide the User to access the recommended methods for engineering and environmental monitoring activities respectively during the post-construction period.

Boxes in which text and tables are incorporated in the above six major program categories in the form of Screens can be edited by selecting the Edit Text button in the User Tools Information on MW for the above six categories are incorporated in the program files.

## IV USAGE OF MUNICIPAL WASTE

### 4.1 International Use:

*Granular base:* Municipal waste combustor ash exhibits many characteristics that suggest it is well suited for use as a granular base material. It is lightweight, and is known to exhibit a relatively high bearing capacity and friction angle. Most of the documented uses for processed MWCA in the United States. There has been little to no documented domestic usage of processed MWCA in granular base course applications in the United States. In Europe a number of countries including Germany, Denmark and The Netherlands routinely use MWCA (primarily bottom ash) in granular base course applications.

### 4.2 India Use:

In order to explore the possibility of using solid municipal wastes in roads, Municipal Corporation of Delhi (MCD), the discussions with Chief Engineers and other officers, a few sites were identified for experimental sections. It was decided to lay the test tracks with municipal wastes along Garhi Randhala - Ladpur road section (length of 500m) near Garhi village for construction. Test sections have been constructed at Garhi Randhala-Ladpur road near Garhi village, Delhi, wherein stabilized municipal wastes were used in sub base layer of road pavement. The performances of these sections were monitored over a period of time and results have indicated that all the test sections constructed using municipal wastes are performing well even after three years.

**Research:** Bulk utilization of these wastes is possible only in civil engineering works like construction of roads and embankments. Central Road Research Institute (CRRI) **has carried out R&D work in using these wastes in road sub bases and embankments.**

**Similarly, the program description file on MWCA provides the user with general information, detailed production and use, engineering and laboratory tests, environmental information, applications and research issues. Developed database is useful in road construction, as well as recommendations for monitoring field trials and also to make the same available to the user at one place which will be Window based and can be used very easily and conveniently.**

## V. DISCUSSION AND CONCLUSION

MV can be utilized gainfully in the construction of roads. Extensive research work **has also** been done in India as well as abroad and the studies have shown that MW has a great potential for its use in road works. However, they have never been utilized on our roads mainly due to lack of information on the subject. As a result million of tons of MW are getting accumulated and causing serious environmental problems.

Keeping the above in view, in the present paper, database on on MW is developed, which contain detail information for the use of above in highway/geotechnical engineering construction application. The database is intended to provide the user with both general and detailed engineering and environmental information on MW. The database is recommended for laboratory engineering tests that can be used to assess the suitability of MW for use in geotechnical - related applications, as well as recommendations for monitoring field trials. This paper assumes that the user is familiar with the Windows environment. This paper provides a general overview of the program, system requirements, and installation requirements.

The developed database contains a pictorial representation of the geographical distribution of production and use rates, engineering properties that are a description and tabular listings of the physical, chemical and mechanical properties of MW. It also includes environmental properties which describe a tabular listing of the trace metal and organic properties. It describes the application of the design, construction, performance and research issues Fig. 11 associated with the use of each MW. A listing and description of recommended laboratory testing and field monitoring methods is included in the database. Finally listing of the references is included in the developed database. The above information is presented in detail in the form of screens. Detailed listing of engineering tests to assess the suitability of MW will be useful in a geotechnical related applications as well as recommendations for monitoring MW field trials. The MW has a great potential for its use in road networks and the developed database on MW would provide the user with both general and detailed engineering and environmental information which will be useful to society. To develop the MW information database the VISUAL BASIC 6.0 is used which provides the flexibility to edit and update the database to respond to new data inputs and also it is user friendly.

## APPENDIX- I

### *Tools used in database:*

#### *User Tools:*

**Print:** The Print button provides the User to obtain a hard copy (printed page) of information presented in the database. The Print button is provided to send the data on the current screen to the printer.

**Add/Delete:** The Add button on the User Tool Bar is only active in the Production and Use, the Engineering Properties, or the Applications Information screens. If the User is in one of these three information screens, the Add button will be enabled and the User may select it to add additional maps to the Production and Use Screen, engineering properties to the Engineering Properties Screen, and applications to the Applications Screen. On all other screens the Add button is disabled.

Also:

Adding Production and Use Information

Adding Engineering Properties

Adding Applications Information

#### *Adding Production and Use Information:*

The Add/Delete button will provide the User to add a new map to the selected tab for the selected W.M. if the User is in

the Production or Use tab of the Production and Use Information Screen. The User may add maps to either the Production or Use screens.

The Add button is provided to lead the four steps to add a new User map.

#### **Step 1:**

The first step will require the User to provide the name of the new map. The User is required to enter a new location name in the text display labeled New Location Name. The text display will have the default text "Enter Location Name Here". Once the new name is provided, press the Next> button to proceed to Step 2.

#### **Step 2:**

This step presents the User with two options for selecting a map for the new location. The first option is "Select from a default list of maps included with the program" and is the default option. The second option is "Import a bitmap (\*.bmp) or a metafile (\*.wmf)." To select the second option, click the check box next to the option.

If the User selects the first (or default) option of adding a default map included with the program, the User should select a map from the list of 51 maps which are listed in the drop-down list box labeled Select Default Map. The default maps within the program include a map of the United States and one map for each state.

If the User selects the second option of importing a picture, the drop-down list box labeled Select Default Map will disappear and replaced by a button labeled Import Picture. This button will open a standard Windows Open Dialogue box, allowing the User to import any valid bitmap (\*.bmp) or metafile (\*.wmf). Once the picture to be imported is selected, the name of the file to be imported will be displayed below the Import Picture button. Press the Next> button to proceed to Step 3, the Previous< button to return to Step 1, or the Cancel button to exit.

#### **Step 3:**

Step 3 allows the User to decide whether or not to include a table along with the map. To include a table the User should click the Yes, include a table button. The default option is, not to include a table.

If Yes, a Table would be selected, then press Next to proceed to Step 4, Previous to return to Step 2, or Cancel to exit.

If No, do Not Include a Table would be selected, then press Finish to create the new map, Previous< to return to Step 2, or Cancel to exit.

#### **Step 4**

If the User decides to add a table along with the map, then Step 4 allows the User to construct the table, which will be added with the map. The table is constructed by entering a name for each column that will be added to the new table. To enter a column name in the new table the User should type the name in the text display labeled Enter Column Name. Once the name is entered, click the Add Column> button. This will move the column name to the List of Columns, which will be added to the table. To remove a column from the list, select its name in the List of Columns display and select the Remove Column button.

Once a table is defined the User can press the Finish button to add the new map to the selected Production or Use tab, Previous< to return to Step 3, or Cancel to exit.

#### *Adding Engineering Properties:*

If the User is in the Engineering Properties Information Screen, the Add button will permit the User to add a new engineering property to the selected tab for the selected W.M. The User adds properties separately for each respective tab. The new property will be added to the currently selected tab.

When the Add button is pressed the User will be presented with a series of screens that will lead the User through the three stages by adding a new engineering property.

##### **Step 1**

The first step will require the User to provide the name of the new location. The User is required to enter a new location name in the text display labeled New Location Name. The text display will have the default text "Enter Location Name Here".

Once the new name is provided, press the Next> button to proceed to Step 2.

##### **Step 2**

This step allows the User to decide whether or not to include a table with the location. To include a table the User should click the Yes, Include a Table button. The default option is not to include a table.

If tables are to be included, then press Next> to proceed to Step 3, Previous< to return to Step 1, or Cancel to exit.

If No, do not Include table would be selected, then press Finish to create the new location, Previous to return to Step 1, or Cancel to exit.

Once a table is defined (if Yes, Include Table is selected) the User can press the Finish button to add the new location to the selected tab of the Engineering Property Section, Previous< to return to Step 2, or Cancel to exit.

##### **Step 3**

If the User decides to add a table to the new location, then Step 3 allows the User to construct the table, which will be added with the text box. The table is constructed by entering a name for each column that will be added to the new table. To enter a column name in the new table the User should type the name in the text display labeled Enter Column Name. Once the name is entered, click the Add Column> button. This will move the column name to the List of Columns that will be added to the table. To remove a column from the list, select its name in the List of Columns display and select the Remove Column button.

Once a new location is created it can be edited by clicking the Edit button in the User Tools.

#### *Adding Applications Information*

In the Applications Information Screen, the Add button can be pressed to add a new application for the selected W.M. The new application will be added to all tabs.

When the Add button is pressed the User will be presented with the Add Application Screen. This screen will lead the

User through eight steps to add an application to the Applications Information Screen.

##### **Step 1**

The first step will require the User to provide the name of the new Application. The User is required to enter a new location name in the text display labeled New Application Name. The text display will have the default text "Type Application Name Here." Once the new name is provided, press the Next> button to proceed to Step 2.

##### **Step 2**

Step 2 allows the User to decide whether the tables to be included or not along with the Application. A table can be included for each of the six Application Subcategories (tabs). To include a table for a Subcategory, the User should check the name of each Subcategory where a table should be included. The default option is, not to include any tables.

If Yes, Include Table would be selected, then press Next to proceed to Step 3, Previous< to return to Step 1, or Cancel to exit.

If no tables are to be included, then press Finish to create the new Application, Previous to return to Step 1, or Cancel to exit.

##### **Steps 3**

If the User decides to add tables to the new application, then Steps 3 and 4 allow the User to construct the tables that will be added with the application. Each table is constructed by entering a name for each column that will be added to the new table. To enter a column name in the new table the User should type the name in the text display labeled Enter Column Name. Once the name is entered, click the Add Column> button. This will move the column name to the List of Columns that will be added to the table. To remove a column from the list, select its name in the List of Columns display and select the Remove Column button.

Once a table is defined (if Yes, Include Table is selected), the User can press the Next button to proceed to the next step to define the next table, Previous to return to Step 3, or Cancel to exit. After constructing the last table, press the Finish button to add the applications.

Once a new application is created it can be edited by clicking the Edit button in the User Tools.

#### *Editing a Map*

The created new map can be edited so that the Edit Map Screen will appear. The User can use the drawing tools to add details to the map. The Save Changes button can be pressed to save any changes that the User has made to the map. The Load New button allows the User to import another map into the property, which would replace the current map. The Export button allows the User to save the map for use outside the program.

##### *Edit Text*

The table and text displays in the W.M. database program are set so that they are not editable by the User unless the

Edit button is pressed. The Edit button is located in the User Tools of the Main Controls.

The Edit Text button will display all the tables and all the editable text in each information screen and the screen will change from a white background to a gray background indicating that the User may now edit and add information. When the program is in edit mode, the Edit button will remain depressed and a light flashing red and yellow will appear adjacent to the Edit button. When the Edit button is depressed, the flashing light will disappear, the button will return to its raised position and the tables and text displays will return to a white background and become uneditable until the Edit button is selected again.

When the tables are in edit mode a blank row will appear at the bottom of the table to allow the User to enter new information. When the blank row is filled, a new blank row will appear to allow the User to enter new rows of data if desired.

To enter data into a table, the User should click the cell in which he wants to enter text and begin typing. Once the text is entered, press the Enter key on the keyboard to input the data and move to the next cell.

To enter or change data in a text display, the User should click the text display where he would like to begin typing. The cursor can be moved around in the text display using the arrow keys on the keyboard. Once the text is entered the data will be automatically updated.

When the program is not in Edit mode, the only option the User is permitted to perform with the text display is to copy selected text using standard Windows copy commands. The table and text displays in the W.M. database program are set so that they are not editable by the User unless the Edit button is pressed. The Edit button is located in the User Tools of the Main Controls.

When the Edit Text button is pressed by the user, all the tables and all the editable text displays in each information screen and it will change from a white background to a gray background indicating that the User may now edit and add information. When the program is in edit mode, the Edit button will remain depressed and a light flashing red and yellow will appear adjacent to the Edit button. When the Edit button is depressed, the flashing light will disappear, the button will return to its raised position, the tables and text displays will return to a white background and become uneditable until the Edit button is selected again.

When the tables are in edit mode a blank row will appear at the bottom of the table to allow the User to enter new information. When the blank row is filled, a new blank row will appear to allow the User to continuously enter new rows of data if desired.

To enter data into a table, the User should click the cell in which he wants to enter text and begin typing. Once the text is entered, press the Enter key on the keyboard to input the data and move to the next cell.

To enter or change data in a text display, the User should click the text display where he would like to begin typing. The cursor can be moved around the text display using the arrow keys on the keyboard. Once the text is entered the data will be automatically updated.

When the program is not in Edit mode, the only action the User is permitted to perform with the text display is to copy selected text using standard Windows copy commands.

## APPENDIX-II

### *VISUAL BASIC tools:*

Over the past several years GUI Systems have widely accepted as front end and SQL Server as backend. The combination of Visual Basic 6.0 (as Front end) and MS-Access (as back end) is power full combination. Visual basic is one of the best GUI for developing any kind of windows application. Some of the best Features, which this combination provides, are as follows:

- Easy and fast access of data
- Flexibility in data modeling
- Reduces data storage and redundancy
- Data independence
- Data sharing
- Visual basic menu bar

### *Introduction to VISUAL BASIC 6.0:*

Visual Basic is an event-driven programming language. Programming in Visual Basic is done visually, which means that as you design your application you will know how your application will look on execution. You can therefore change and experiment with the design to meet your requirement. The main advantage of Visual Basic is that it is a Rapid Application Development Tool. This is the main reason why Visual Basic is extensively used as a prototyping of language. Visual basic works with all the RDBMS without any problems and provides easy methods for inserting, updating and accessing the data from the database.

### *Tools used*

To develop a user graphical interface it required choosing a platform, which can generate forms with case flexibility. The Visual Basic environment is fully integrated and supports the full development cycle. Visual Basic fully supports all phases of the Windows software life cycle-from design to development to development.

### *Important tools*

- ADO (Active X Data Object)
- Data Environment
- OLE DB Support
- Form
- Menu Bar
- Tool Bar
- Properties Window

- Code Editor Window
- Object Browser
- Form Layout Window
- Context Menu
- Standard Tool Bar
- Microsoft Tabbed Dialog Control 6.0
- Microsoft Data Grid Control 6.0 (OLEDB)
- Microsoft ADO Data Control 6.0 (OLEDB)
- Microsoft Common Dialog Control 6.0
- 

#### *ADO (Active X Data object):*

This new data access technology features a simpler object model, better integration with other Microsoft and non-Microsoft technologies, a common interface for both local and remote data access, removable and disconnected record sets, a user-accessible data binding interface and hierarchical record sets.

#### *DATA ENVIRONMENT:*

The Data Environment designer provides an interactive, design time environment for creating ADO object. These can be used as a data source for data-aware objects on a form or report, or Ms accessed programmatically as method and properties exposed off of the Data Environment object. The Data Environment designer supports and all the functionality of Visual Basic's User Connection designer, as well as additional feature, including drag and drop, hierarchies, grouping and aggregate.

#### *OLE DB SUPPORT:*

OLE DB is a set of COM interface that provide applications with uniform access to data stored in divers information source, both relational and non-relational. These interfaces support the amount of DBMS functionality appropriate to the data source, enabling it to share its data. All the new data bound controls, the Data Environment and Data Report designer are OLEDB-aware.

#### *THE COMMON DIALOG CONTROL:*

The Common Dialog Control is a peculiar one. It provides its services to the application, but it doesn't need to be displayed on the form at runtime (similar to the Timer control). The common Dialogs Control provides the following built-in-Windows dialog boxes:

- **Open:** It lets users to select a file to open.
- **Save As:** It lets users select or specify a filename in which the current document will be saved.
- **Color:** It lets users select colors to specify custom colors.
- **Font:** It lets users select a typeface and style to be applied to the current text selection.
- **Print:** It lets users select and set up a printer.
- **Help:** The Help common dialog box displays Help topics.

#### *MENU BAR:*

The menu bar helps you to perform various tasks and it includes a list of options. Each option on the menu bar has a drop-down list of items that are related to the option chosen from the menu bar.

#### *FORM:*

A form is one of the main building blocks of Visual Basic application. Users interact with the controls on a form to obtain the desired result. Most of the applications written in Visual Basic include at least one form.

#### *TOOL BOX:*

The toolbox is a window that provides you a set of tools that are used at design time to place controls on a form.

#### *PROPERTIES WINDOW:*

The properties window list the property settings for the form or controls that you select. A property is a characteristic of an object, such as size, caption or color. The property window displays the property of only one object at a time- the one that is currently selected.

#### *CODE EDITOR:*

The Visual Basic Code editor is the window where most of the code is written. It is a special word processor with a number of features that help you to write a Visual Basic Code easily.

#### *OBJECT BROWSER:*

The object browser is another window available from the View menu. It gives a list of objects that can be used in the project and gives you a quick way to navigate through the code. It also displays classes, properties, methods events and constants in your project. Objects from other applications can also be used.

#### *FORM LAYOUT WINDOW:*

Form layout window allows you to visually poison the forms at design time. All forms that are visible in the environment are shown in the form layout window.

#### *CONTEXT MENU:*

Visual Basic provides context menus that contain short cuts to the frequently performed actions. To open a context menu, you need to click the right mouse button on the project being used.

#### *STANDARD TOOLBAR:*

The standard toolbar has buttons for the most frequently used commands in Visual Basic. Some of them are Open Project, Save Project, Cut, Copy, Paste, start, break, and Add Form. It can also contain buttons for the toolbox, the properties Window and other features.

#### *BOUND CONTROLS:*

Bound data controls are designed to permit you to create data-access applications that require little or no coding. To use any of these "data-aware" bound controls, you will need to place one or more Data controls on your form. The Data control establishes a link between the database and any bound controls used to manipulate the data.

The Toolbox displays all the standard Visual Basic controls including the Data control and data-aware (bound) controls. If the bound control you need is not displayed in the Toolbox, you can use the Tools Custom Controls dialog to add them to your project. In order for you to write code that references the Data Access Objects (DAO) that the Data control creates, you

may need to use the Tools References dialog to activate the Microsoft DAO 2.5 Object Library. Some of the controls listed below also have libraries that require activation using the Tools References dialog.

There are ten data-aware controls in addition to the Data control provided with Visual Basic:

**Data Control:** Use to provide access to data in databases through bound controls on your form. Creates and manages Database and Record set objects for use by bound controls. Required for use with all other bound controls.

**DBCombo:** Use to draw a data-aware combination list box and text box. The list can be filled automatically from a Data control. The user can either choose an item from the list, or enter a value in the text box and can be used to provide read/write-access to a specified text data field selected from the list.

**DBList:** Use to display a Data control-generated list of items from which the user can choose one. The list can be filled automatically from a Data control and used to provide read/write access to a specified text data field selected from the list.

**DBGrid:** Use to draw a data-aware grid composed of multiple records. The grid can be filled automatically from a Data control. The user can either choose an item from the grid, or enter a value in the new record can be used to provide read/write-access to a Record set.

Introduction to Database:

A database is a collection of records stored in the tables. It has a set of rules and tools to manage this record.

**Label:** Use for text that you don't want the user to change, such as a caption under a graphic can be used to provide display-only access to a specified text data field.

**Text Box:** Use to hold text that the user can either enter or change. The Text Box control is a small text editor that provides all the basic text editing facilities:

-Inserting and selecting text  
-Scrolling the text if it doesn't fit in the controls area and  
-Exchanging text with other application through the Clipboard.

**Check Box:** Use to create a box that the user can easily choose to indicate if something is true or false, or to display multiple choices when the user can choose more than one. Can be used to provide read/write-access to a specified Boolean or bit data field.

**Combo Box:** Use to draw a combination list box and text box. The list is filled with the Add Item method. The user can either choose an item from the list or enter a value in the text box. Can be used to provide read/write-access to a specified text data field selected from the list. See DBCombo control

**List Box:** Use to display a list of items from which the user can choose one. The list is filled with the Add Item method. The user can choose an item from the list. Can be used to

provide read/write access to a specified text data field selected from the list.

**Picture Box:** Use to display a graphical image from a bitmap, icon, or metafile on your form. Can be used to provide read/write-access to a specified image/binary data field.

**Image:** Use to display a graphical image from a bitmap, icon, or metafile on your form. Images displayed in an image control can only be decorative and use fewer resources than a picture box. Can be used to provide read/write-access to a specified image/binary data field.

**Executable file:** So far, I have been executing applications within Visual Basic's Environment. However, it can't expect the users of the application to have Visual Basic installed in their systems. As I want to develop an interesting application, I won't feel like giving away the code of the application (the SOURCE CODE, as it's called). Applications are distributed as **executable files**, along with their support files. The user of this application can't see the "source code", and the Application can't be modified or made to look like someone else's application (that does not mean it can be copied, of course).

In short we can say, "An Executable File is a binary file that contains instructions only the machine can understand and execute. The commands stored in the executable file are known as "Machine Language".

1. A Database represents some aspect of the real world, sometimes called the "MINIWORLD". Changes of the Miniworld are reflected in the database.
2. A Database is logically coherent collection of data with some inherent meaning. A random assortment of data cannot correctly be referred to as database.
3. A Database is designed, built and populated with data for a specific purpose. It has an intended group of users and some preconceived applications in which these users are interested.

In other words, a Database has some source from which data are derived. A Database may be generated and maintained manually or it may be computerized. A computerized Database may be created and maintained either by a group of application programs written specifically for that task or by the Data Base Management System (DBMS).

A DBMS is collection of program that enables users to create and maintain a database. The DBMS is hence a general-purpose software system that facilitates the process of defining, constructing and manipulating database for various applications.

1. **DEFINING:** - Defining a database involves specifying the data types, structures and constraints for the data to be stored in the database.
2. **CONSTRUCTING:** - Constructing the database is the process of storing the data itself on the same storage medium that is controlled by the DBMS.

**MANIPULATING:** - Manipulating a database includes such functions as querying the database to retrieve specific data,

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Choosing reference tab in introduction screen, a listing of references will appear as shown in Fig 12.



Fig.1. Municipal Waste Login-Screen

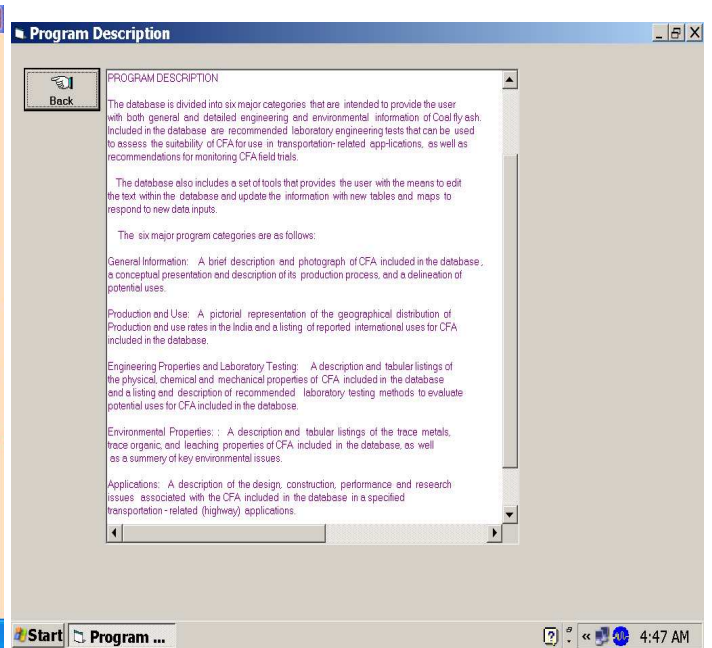


Fig.3. Program Description- Screen

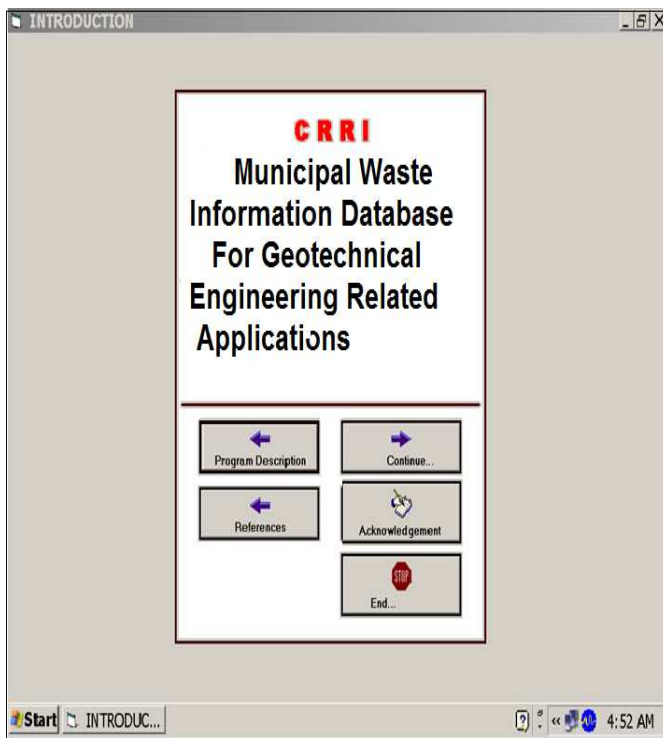


Fig.2. Introduction-Screen

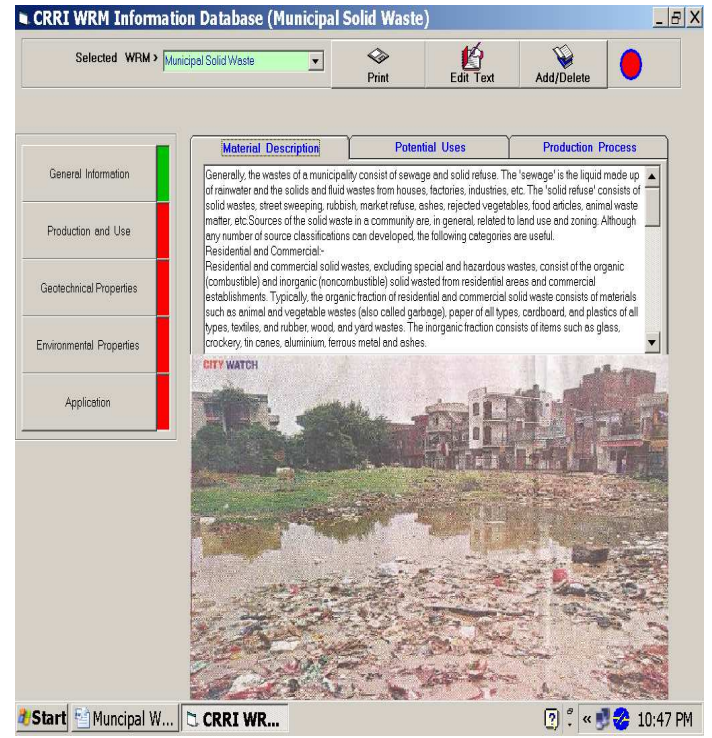


Fig.4. General Information on Municipal Solid Waste-Screen



Fig.5. General Information Material Description- Screen

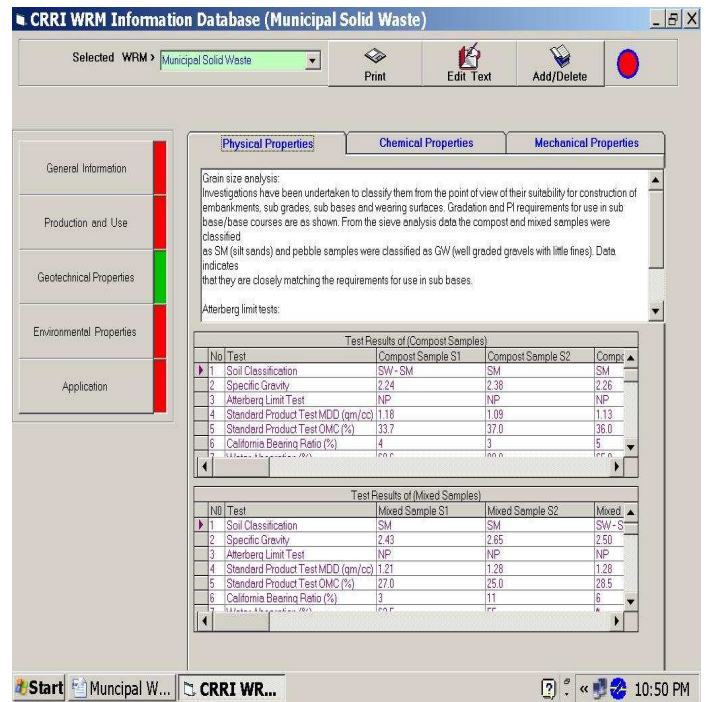


Fig.7 Municipal Waste Geotechnical Properties- Screen

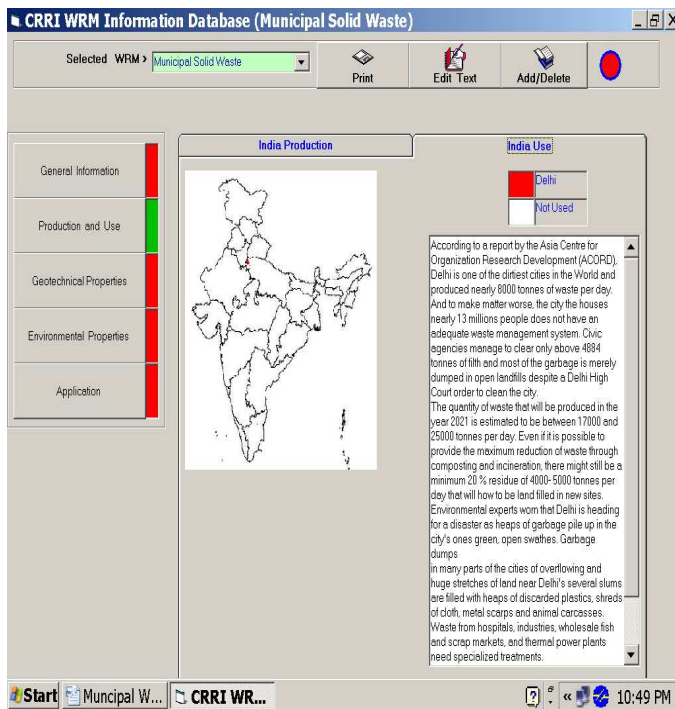


Fig.6. Municipal Waste Utilization in India –Screen

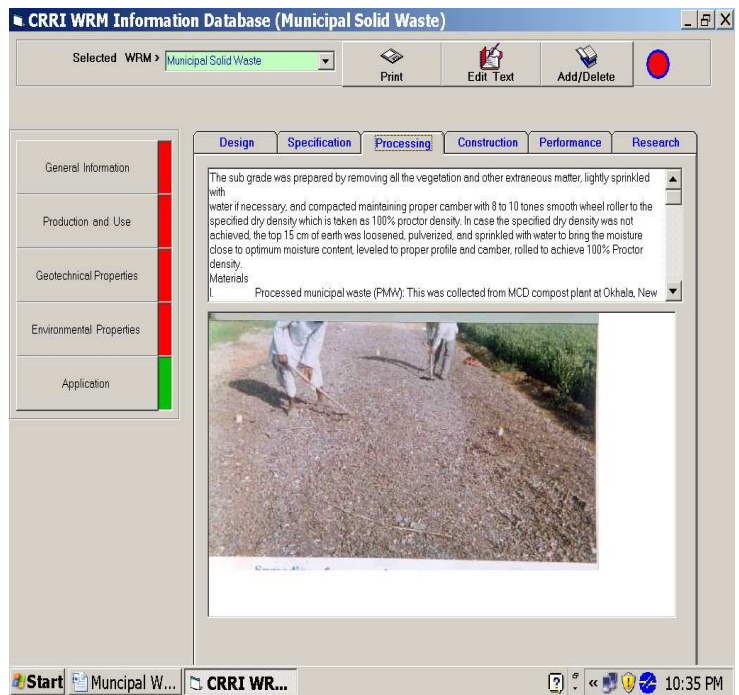


Fig.8. Application Processing-Screen

## A knowledge-based database on municipal waste in road construction applications



Fig.9. Construction-Screen



Fig.11. Research – Screen

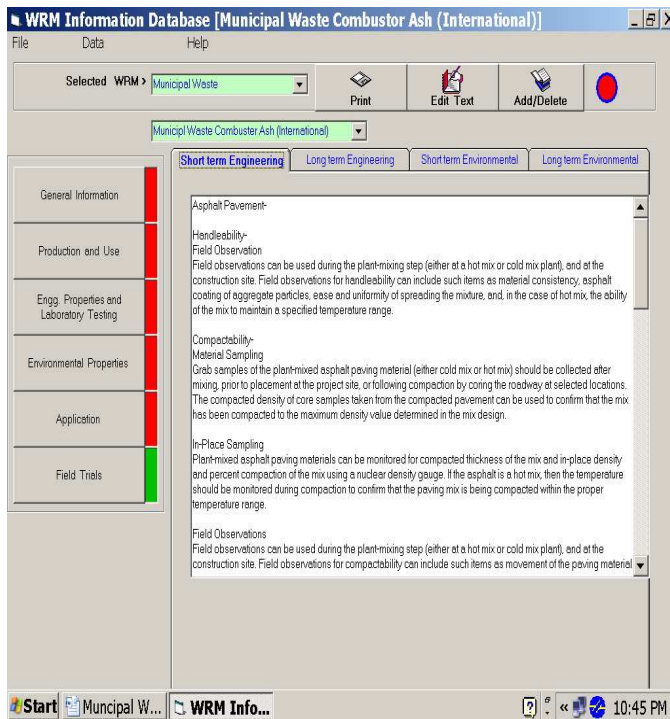


Fig.10 Field Trials Screen

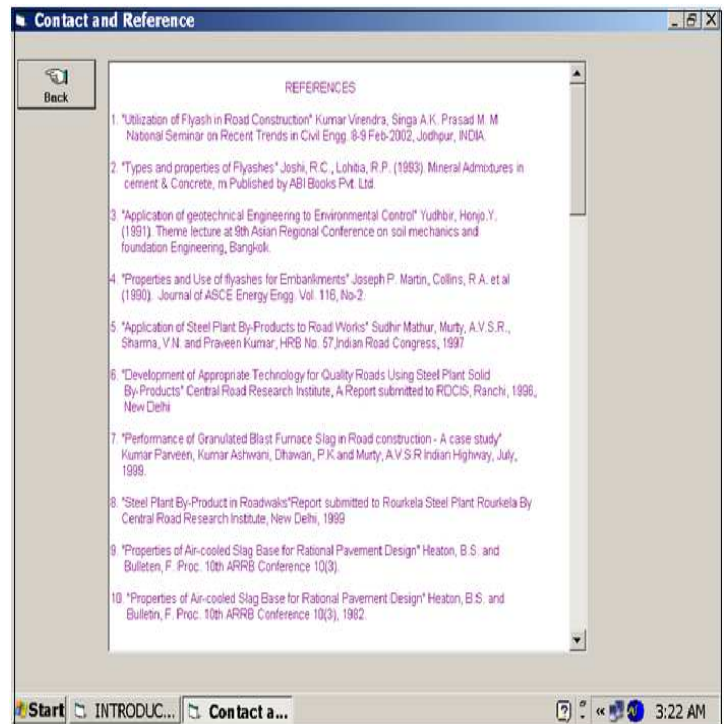


Fig.12. List of References-Screen