1. Description. This Item shall govern performance of Deep Dynamic Compaction (DDC) of landfill materials within the area shown on the plans, and related work. DDC is a process whereby a heavy tamper is raised and dropped from specified heights to impact into the ground surface thereby transmitting high compaction energy into the soil and existing land fill materials.

The scope of work of this specification section includes site preparation, excavation and rough grading of the DDC work area, safety provisions as required to maintain traffic and health and safety provisions for the work activities, performance of the DDC, crater filling and embankment construction to the subgrade elevations shown on the plans, and static load tests for densification verification.

The scope of work includes incidental landfill material excavation adjacent to underground utilities that will be left in-place and protected against dynamic impact and displacement from the DDC. The scope of work also includes handling and disposal of the waste material in accordance with TNRCC regulations.

The DDC work shall be performed by a Specialty Contractor for this construction method, who can meet the requirements of the contract documents. The DDC Contractor shall furnish all supervision, equipment, labor and materials necessary for completion of the DDC.

The objective for the DDC is to reduce the compressibility of the landfill after DDC to one-fourth (1/4) or less of the compressibility in the unimproved state before DDC, as determined by the static load tests.

2. Qualifications. The Specialty Subcontractor shall be regularly engaged in DDC work and have successfully completed projects of similar nature. The following written statements shall be provided by the Specialty Contractor to the Engineer prior to receiving approval to do the work:

1. Providing proof of at least five (5) years of experience with DDC work, and at least three (3) years experience by the person to be in charge of the work on this project.

2. Naming and describing at least three (3) DDC projects similar in scope and nature to this project. Descriptions shall include design consultant's and owner's name and phone number for each project, energy input utilization of between 10 and 20 tons dropped from heights of up to at least 70 feet, to improve soil for bearing capacity and landfill densification, using free fall and single line.
Approval of the Specialty Contractor shall in no way implies acceptance or responsibility by TxDOT of the Specialty Contractor's ability to perform the work.

3. Sequence of Work. The areas subject to DDC shall be prepared by excavation and removal of soils overlying the landfill materials as shown on the plans. Excavation shall be in accordance with Item 110. A soil blanket two (2) feet thick shall be maintained in the densification area.

Traffic barriers and security fencing shall be installed as shown on the plans prior to start of the DDC work for each Phase.

The DDC shall be performed in two (2) Phases as shown on the plans. The energy application within each Phase shall be in two (2) high-energy passes and one (1) low energy ironing pass.

Incidental landfill material excavation, handling and disposal as necessary to protect existing utilities, shall be interfaced with the DDC as indicated on the plans.

The craters caused by the DDC shall be backfilled as the work progresses for each high-energy pass. Craters with depths exceeding specified criteria shall be filled with stone and subjected to additional high energy compaction at the time of each occurrence.

The soil blanket shall be restored each day to cover any material of the landfill.

One (1) load test (Test 1) shall be performed before start of DDC application to establish the compressibility of the landfill material; and two (2) load tests shall be performed to verify the DDC procedures and achieved degree of densification. The first verification test shall be performed at the beginning of the first DDC phase (Test 2) and the second verification test shall be performed at the beginning of the second DDC Phase (Test 3).

Embankment shall be constructed in accordance with Item 132, after completion of the ironing pass and subgrade compaction by vibratory roller.

4. Equipment. DDC shall be performed with the following equipment:

(1) Cranes. At least two (2) operating cranes capable of performing the work shall be provided. Each crane shall have a minimum capacity of 100 tons. The cranes shall be equipped with a 1-1/8 inch minimum diameter cable attached to a single free spool or mechanical drum to allow free fall, tag line or swivel to control rotation of the weights, and safety equipment as required by local, state and federal law for this type of work.

Each crane shall be equipped with an automatic device to count the number of drops that have been performed over a 24-hour period of time.

(2) High Energy Tampers. At least two (2), tampers, each with a total weight of at least 15 tons shall be provided. The tampers shall be cylindrical or octagonal in shape with a flat base whose area shall be between 22 and 35 square feet. High energy tampers shall be designed and manufactured for drops of at least 70 feet.
(3) Low Energy Tamper. At least one (1) tamper with a total weight of at least 11.5 tons shall be provided. The tamper shall be square in shape with a flat base whose area is between 36 and 50 square feet. Low energy tamper shall be designed and manufactured for drops of at least 30 feet.

(4) The tampers shall be properly proportioned and have lifting devices to assure that they will remain vertical during free fall to apply a uniformly distributed impact through the base area. The actual weight and dimensions of each tamper shall be verified by a certified weight slip. The weights shall be made of material capable of transferring maximum energy impact to the ground when freely dropped from the specified minimum height, and preclude being damaged during the operations, and as approved by the Engineer. The need for repair or replacement of damaged tampers shall be as determined by the Engineer.

(5) The Contractor shall provide spare tampers and other spare equipment as required to effectively execute the work.

(6) Earthwork construction equipment for excavation and embankment construction, including front-end loader for crater backfill, dozer for grading the DDC work area, and sufficient rollers for subgrade compaction.

5. Submittals.

(1) Prior to commencement of the DDC operations, the Contractor shall submit a work plan and drawings for approval by the Engineer. The plans and drawings shall be sealed by a Registered Professional Engineer registered in the State of Texas, and shall include the following:

1. Schedule and sequence of construction.
2. High and low energy tamper weights, materials and details.
3. Crane specifications.
4. Plan for installation of barrier and fences.
5. Method of protection and observation or monitoring of existing utilities and other installations shown on the plans.
6. Grid pattern layout for each pass. The grid patterns shall be submitted on a scale plan (1" = 10') with each drop location assigned a reference number. The Contractor shall revise the layout based on any field changes.
7. Static load test procedure.
8. Surface water control plan.
10. Plan for identification handling and disposal of waste excavated incidentally for protection of utilities. The plan shall identify the transporter and the permitted solid waste disposal facility.

(2) The Contractor shall submit reports prepared by an Independent Registered Professional Engineer, registered in the State of Texas, for the Static load tests performed. The report for each test shall be submitted within three (3) working days after completion of the test. The reports shall include:
1. Result of soil boring obtained at the load test location.
2. Actual location of load test, height and volume of surcharge fill placed.
3. Settlement plate elevation survey data, and time/settlement plot.
4. Evaluation of densification results as shown by the load test.

(3) The Contractor shall submit the following records as available on a weekly basis, during progress of the work:

1. Ground elevation surveys after DDC pass completion and regrading.
2. Vibration monitoring records. Instant readout results shall be available at the place of work for each day's operation.
3. Survey data for monitoring of underground installations to be protected.
4. Records of waste material disposal, including truck volume measurements, receiving documents from the waste disposal facility, and results of any tests performed.

(4) The Contractor shall submit the following for each day that DDC work is performed:

1. DDC recordings entered on the grid plots. For high energy passes; show the number of drops as recorded for each impact point. For low energy passes; show the number of drops applied on the area subject to the ironing pass procedure for the day.
2. Volumes of rock fill placed in craters. Craters filled with rock shall be identified on the grid plots.
3. Number of drops performed with high and low energy tampers according to automatic recording device.

(5) The Contractor shall submit upon completion of DDC ironing pass and surface compaction, but before start of embankment fill construction within an area of work:

1. Survey cross-sections of the densified ground surface at 100 foot intervals.

(6) The Contractor shall submit upon completion of all DDC work:

1. A DDC summary report to include a description of actual procedures, the completed grid diagrams, survey data, and final work quantities including energy applied by unit areas and job totals.
2. Postconstruction structural survey.

6. Materials. Embankment materials shall conform to Item 132, Type A, Cl 2. Embankment material may include reclaimed asphaltic pavement (RAP). Soil for crater backfill shall consist of coarse-grained granular soils as defined by the Unified Soil Classification System (TxDOT Foundation Exploration and Design Manual, Chapter II), except that clayey sand shall not be used. Stone for crater backfill shall consist of gravel, stone or broken concrete with a maximum particle size of 12 inches and a sand content of 15 to 30 percent (passing no. 4 sieve). Work blanket and waste cover shall be maintained with embankment material.
7. Procedure.

(1) Traffic Controls. Traffic controls, barriers and fences shall be installed as shown on the Traffic Control Plan for each phase of work.

(2) Existing Improvements. All utilities and other surface and subsurface installations shown on the plans to be preserved shall be located and identified, and isolation trenches shall be constructed as shown on the plans to provide protection of existing installations. Utility protection may be modified in the field depending on the observed influence from the DDC, and as directed by the Engineer.

(3) Landfill Cover Excavation. After removal of existing pavement and other surface improvements, the landfill cover soil in the DDC work area shall be excavated to leave a two (2) feet thick surface cover of soil over the waste (the work blanket). The work blanket thickness shall not be less than two (2) feet, but may be increased over localized depressions in the top elevation of the waste, as required to obtain a sufficiently level DDC work area. The excavated landfill cover material shall be stockpiled and protected for use in embankment construction. Small pit excavations, as directed by the Engineer, shall be used to check the thickness of the work blanket. The Contractor shall avoid excavating into the waste. The cover shall be immediately restored should the waste be accidentally exposed. A stable slope shall be maintained against the traffic lanes.

(4) Grading. The DDC area shall be graded at all times to provide drainage and a sufficiently level surface for the work. Storm Water Pollution Prevention Plan measures shall be implemented as necessary or as directed by the Engineer.

(5) DDC Layout. The limits for the DDC work shall be as shown on the plans. DDC impact points shall not be located closer to existing utilities and other improvements to be preserved than shown on the plans, and as determined to be safe by the Contractor.

The planned impact point grids for the two (2) high energy passes are shown on the plans based on 12 feet spacing for each pass, to be offset six (6) feet in both longitudinal and lateral directions between the passes. This planned grid pattern may be modified in the field based on the achieved results.

The impact points for the low energy pass shall be overlapped to provide continuous coverage. The DDC impact point grid for the first pass shall be staked or flagged. The center of each point shall be flagged. Reference markers shall be placed outside the DDC work area for each row of impact points. The DDC impact point grid for the second pass shall be staked or flagged after site regrading. The offset of the second pass relative to the first pass shall be verified based on the reference markers.

(6) Densification (High Energy Passes). The high energy passes shall include nine (9) drops at each impact point with a 15 ton tamper falling from 60 feet height. Acceptable tolerance for the distance between the center of the tamper and the marked grid point location is 12 inches. The crater depths shall be limited to six (6) feet. If a crater depth exceeds six (6) feet.
for nine (9) drops or less, then the crater shall be backfilled with stone and densified by a new series of nine (9) drops. The craters within the work area shall be backfilled each day. Craters of six (6) feet or less depth shall be backfilled with soil.

A section of work shall be regraded and the two (2) feet thick work blanket restored by filling, grading and dozer track compaction before proceeding with the second high energy pass. The energy application and crater criteria shall be the same for the second as for the first high energy pass.

The second high energy pass may follow after the first pass after 48 hours if there is no evidence of heave, or other signs of pore pressure build up. The second pass may be further delayed if heave occurs, or the DDC procedure may be modified as directed by the Engineer.

(7) Densification (Low Energy Ironing Pass). A section of work shall be regraded and the low energy ironing pass delayed after the second high energy pass as described in Subarticle 7.(6). The low energy pass shall include two (2) drops impacting each area with a 11.5 ton tamper falling from 30 feet height. The footprint of the impacts shall be overlapping in each row and the center of impact shall be moved for each drop a distance equal to half the width of the tamper. The impact footprints between rows shall overlap about one (1) foot.

(8) Soft Areas. The Engineer may direct additional energy applications at any stage of the DDC, should there be evidence of soft areas or locations with a lesser degree of densification.

(9) The DDC procedures will be evaluated by the Engineer based on the static load tests in regard to achievement of the objective to reduce the compressibility of the landfill after DDC to one-fourth or less of the compressibility in the unimproved state. The Engineer may direct modifications to the compactive effort depending on the test results.

8. Surface Compaction and Embankment Construction. The DDC area shall be regraded and compacted with a vibratory roller after completion of the ironing pass. The compaction shall be performed with a vibratory roller with a minimum static weight of 10 tons. At least six (6) passes (round trip) shall be performed with the roller in the vibrating mode over the entire area forming the subgrade for embankment construction. Embankment construction shall be performed in accordance with Item 132, using stockpiled material from the initial cover excavation. Embankment material shall be borrowed as necessary to reach the grades shown on the plans.

9. Landfill Material Handling. Excavation of landfill material, or uncovering of landfill material, shall be avoided as far as practical. It is expected that landfill material will be exposed in the high energy pass craters. The craters shall, therefore, be backfilled each day as required in the DDC procedure. Landfill material accidentally uncovered during excavation of existing cover, shall be covered by the two (2) foot thick working blanket the same day.
It is estimated that approximately 100 cubic yards of non-hazardous municipal solid waste may be excavated from the unpermitted landfill as a result of activities necessary to protect utilities. The Contractor shall be responsible for proper management of any excavated waste material as follows:

1. Solid waste and soil shall not be mixed during excavation. Waste materials shall be segregated during handling from excavated soil and other clean materials.

2. Any solid waste removed from the landfill shall be properly transported to a permitted solid waste facility that is authorized to receive the waste.

3. The Contractor shall make all necessary arrangements for the disposal at the waste facility, including any analytical testing as may be required to characterize the waste for acceptance by the facility.

4. Any waste temporarily stored at the construction site shall be stored in closed or covered containers which are leakproof and in good condition. Waste shall be stored in such a manner that it does not constitute a fire, safety, or health hazard and shall be contained so as not to result in litter. Waste shall be managed in such a manner as to minimize the potential for nuisance odors.

5. In general, any excavated waste material shall be managed in accordance with Texas Natural Resource Commission Municipal Solid Waste Regulations as specified in the Texas Administrative Code, Title 30, Chapter 330.

10. Protection of Existing Installations. The Contractor shall develop and implement detailed plans for protection of existing underground installations and other improvements that must be preserved as shown on the plans. This shall be considered subsidiary to the DDC work and will not be paid for directly. The installations to be protected shall be isolated from the dynamic impact and ground displacements by distance, or by excavation of trenches as conceptually shown on the plans. Pits for placement of observation points shall be provided for survey measurements of potential horizontal and vertical movement of underground installations as shown on the plans. The Contractor shall survey these observation points on a daily basis while DDC work is performed in the vicinity.

11. Quality Control. The Contractor shall supervise the DDC to ensure compliance with the plans, specifications, and the provisions of the Contractor's documents as defined in Article 5. The Contractor shall keep complete records of the work performed, including date and time of work, pass number, impact locations as defined by the applicable grid, weight properties, number of drops, depth of penetration of the tamper, observation of heave, and crater filling with stone or soil. Records shall be kept by the Contractor for a minimum of three (3) years, and shall be available to the Engineer at all times.

The Engineer will inspect the DDC work. The Contractor shall mark the tamper hoisting cable to allow observation of the lift height from a safe distance.
The Contractor shall perform static load tests at the location indicated on the plans and as directed by the Engineer. The testing shall be under the observation of an Independent Registered Professional Engineer, registered in the State of Texas, retained by the Contractor, who shall submit a certified test report. The objective for the tests is to verify the use of a DDC procedure resulting in a reduction in compressibility to one-fourth or less of the compressibility in the unimproved state before DDC.

Three (3) load tests shall be performed. The purpose for the first test shall be to determine the compressibility of the landfill material in the existing unimproved state. The test shall be performed after the area has been prepared for DDC but before energy application. The purpose for the second test, to be performed adjacent to the first test in the beginning of the Phase 1 DDC work, shall be to determine the remaining compressibility of the landfill after complete DDC application. The work in the test section shall in all regards follow the Contractor's planned procedures. Energy application shall include the planned two (2) high energy and one ironing passes. The purpose for the third test shall be to verify the ground response after DDC application, and assess possible differences due to variations in compressibility of the landfill at the beginning of the Phase 2 DDC work.

The Contractor shall obtain at least one (1) soil boring in the area of each load test to verify the depth of landfill material. As far as practical, the load tests shall be performed in areas with approximately 20 feet thickness of landfill material. The only required purpose for the borings is to establish the elevation of the bottom of the landfill and the Contractor may select the boring method accordingly. The soil boring holes shall be backfilled with cement grout.

The load shall be applied by a conical pile of soil with a base diameter of approximately 60 feet and a height of 24 feet above original grade, as shown on the plans. The Contractor may provide an alternate method of load application providing a stress increase at the mid-height of the landfill layer of approximately 2,000 pounds per square foot above the soil pressure due to original grade.

The Contractor shall install a settlement plate, riser pipe and protective plastic casing as indicated on the drawings. The pipe shall be in sections allowing elevation surveys as the soil pile is constructed. The Contractor shall be responsible for fabrication details of plate and pipe connections.

Individual survey readings shall be taken before placement of the fill in the load test pile starts, and at every six (6) feet interval as material is placed to the maximum height. Settlement readings shall be made every eight (8) hours for the first day (24 hours) and every 12 hours for six (6) additional days. The settlement observations may terminate after this series of observations if the settlement rate has been significantly reduced, as determined by the Engineer. The Contractor shall be prepared to continue the settlement observations by daily surveys for an additional seven (7) days, as directed by the Engineer if the settlement rate is still significant after the first seven (7) days of observations. The Contractor shall remove the load test soil pile after completion of the test as required to proceed with the work.
12. Structural Surveys. A preconstruction survey shall be performed on all structures within the right of way. The Contractor shall perform preconstruction surveys of structures outside the right of way, which potentially may be within the zone of influence from the DDC, as directed by the Engineer. The Engineer will arrange for right of entry for performance of such surveys. A Registered Professional Engineer experienced in this type of work and registered in the State of Texas shall perform the survey. The survey shall be comprehensive and shall include a written description, video and photo log of each observed structural defect. A postconstruction survey shall be performed upon completion of the DDC work. This survey shall address the same structures as in the preconstruction survey, and all changes shall be noted.

13. Vibration Monitoring. Vibration monitoring shall be performed during the DDC work. Monitoring shall include structures shown on the plans and located within 300 feet of the area being densified. Vibration monitoring of the concrete slope protection of the American Canal shall be performed as a minimum at three (3) locations. These locations are in vicinity of the beginning, middle and end of the DDC work area as indicated on the plans. The recorded vibrations shall be monitored to assure conformance with the variable particle velocity vs. frequency limits recommended by the United States Bureau of Mines, Report RI-8507 (November, 1980).

The Contractor shall engage a specialist firm to perform the vibration monitoring, or have an experienced operator on-site performing the monitoring task. Before performing the DDC work to be monitored, a properly calibrated seismograph shall be set adjacent to the foundation of the nearest structure in each direction that could be affected. The instrument shall provide instant readout of the measured particle velocity and a permanent record.

DDC operations causing vibrations with a recorded particle velocity exceeding two (2) inches per second at the structure of concern, shall stop until evaluated by the Engineer.

14. Health and Safety Plan. The Contractor shall implement a health and safety plan to include as a minimum for the DDC operations:

1. Protection for off-site personnel and traffic.
2. Protection for on-site personnel.
3. Crane safety to address the crane operations and all parts of the crane affected by the DDC work, such as the crane boom, cables, drum, brakes, clutches, outriggers etc, and the maintenance schedule.
5. Personal health protection for work with solid waste landfill materials.

15. Measurement. This Item will be measured as follows:

The mobilization of equipment specified under "Equipment" to perform deep dynamic compaction application will be measured by the lump sum.
Deep Dynamic Compaction (DDC) High Energy Application will be measured by each drop. Measurement for each drop will be prorated to the drop of a 15-ton tamper from a 60 feet height which equals 900 ton-feet (US Customary Unit).

Rock for crater fill will be measured by the ton in vehicles as delivered.

Waste Handling and Disposal will be measured by the cubic yard in vehicles of uniform capacity. Landfill Cover Excavation will be measured by the cubic yard in accordance with Item 110, Article Item 110.3. Vibration Monitoring shall be considered subsidiary to the DDC high energy application, and will not be measured separately.

Embankment Construction will be measured by the cubic yard in accordance with Item 132, Class 2 Embankment.

Subgrade Surface Compaction shall be considered subsidiary to Embankment Construction item and will not be measured separately.

16. Payment. The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for as follows:

Upon delivery and placement of DDC equipment in good repair and working order to the work site, DDC equipment mobilization as provided under "Measurement" will be paid for at the unit bid price of "Furnishing Dynamic Compaction Equipment". This price bid for DDC Equipment Mobilization will be full compensation for furnishing the equipment, labor, material and documentation as required under "Submittals".

"Deep Dynamic Compaction (DDC) High-Energy Application" as provided under "Measurement" will be paid for at the unit bid price per drop. This price shall be full compensation for the protection of existing work, grading of work area, maintaining minimum two (2) foot thick work blanket and landfill cover, static load tests including soil borings, monitoring surveys and reporting, structural surveys, required documentation, DDC grid pattern layout, DDC low energy applications, vibration monitoring, tools, equipment, labor and incidentals necessary to complete the work.

Rock filling of craters as provided under "Measurement" will be paid for at the unit bid price for "Rock Fill for Craters". This price shall be full compensation for the hauling, handling, placement, soil filling and cover, materials, compacting, tools, equipment, labor and incidentals necessary to complete the work.

Waste handling and disposal as provided under "Measurement" will be paid for at the unit bid price for "Waste Handling and Disposal". This price shall be full compensation for the analytical testing of waste, the Contractor's health and safety program, training, monitoring activities, waste storage, loading and hauling of materials to permitted solid waste disposal facility, tools, equipment, labor and incidentals necessary to complete the work.

Excavation to isolate utilities from DDC effects, and landfill cover excavation will be paid for in accordance with Item 110, "Excavation".
Embankment placement will be paid for in accordance with Item 132, "Embankment".

Subgrade Surface Compaction will be paid for in accordance with Item 132.

Mobilization of all other equipment and resources not addressed under "Equipment", but necessary to complete the work, will be paid for in accordance with Item 500, "Mobilization".

The use and placement of traffic control devices, barricades and fencing will not be paid for directly, but shall be considered subsidiary to Item 502, "Barricades, Signs and Traffic Handling".