Technical Innovation

Case Study

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ABSTRACT

This case study demonstrates how accurate condition assessments and predictive maintenance planning can be integrated using existing client software tools to build a powerful asset management solution. The project involves roof and HVAC system asset quantification, condition prioritization, and five-year preventive maintenance programming on 243 buildings at 14 locations involving 473 roof sections and 2,604 HVAC unit components. The component condition and budget planning data were integrated into a database tool, which is interactive with the owners’ computerized maintenance management system planning and work order control system. Utilizing the component condition and prioritization information, the owner was able to competitively bid and efficiently manage a high-priority repair/replacement project on 22 buildings and 43 roof areas.

SPEAKERS

GARY WILLIAMS, PMP — CONLEY GROUP, INC.

GARY WILLIAMS is a client executive and project manager with an extensive background in K-12 schools, commercial buildings, sports facilities, and historic structures. He possesses proven expertise in facility asset management planning, building envelope design, construction administration, and project management. Williams’ skill set includes managing building envelope assessments, designing and developing facility asset databases, and creating facility asset management plans. He is member of the Project Management Institute and RCI, Inc.

BILL CONLEY, RWC — CONLEY GROUP, INC.

BILL CONLEY is the founder and president of Conley Group, Inc., with over 35 years’ experience in all phases of building envelope design, renovation, and repair. Conley has been an active member of RCI since 1988, having served on the RWC Exam Development Committee. He currently serves as a director of the North Texas Chapter of RCI. Mr. Conley has developed and managed ten roof asset management programs involving over 1,600 facilities and 90,000 square feet of existing roof systems with over $1.1 billion in asset value since 1989.
INTRODUCTION

Effective management of building infrastructure assets, especially those key assets with long-term service lives, requires a long-term asset design and maintenance strategy that recognizes life cycle costs of those systems. Building owners must be disciplined to construct these systems properly and to fund/track/manage internal operations to ensure that critical periodic inspection and maintenance procedures are not deferred/ignored, regardless of funding, staffing, and operational challenges within the business or department. Long-term (capital/balance sheet) assets such as roofing systems, building exterior cladding systems, and HVAC systems must be effectively designed, constructed, and maintained over their 20- to 30-year life cycles in order to optimize performance, reliability, service life, and cost of ownership. Too often, short-term organizational cycles, including personnel changes, staff reductions, funding limitations, management bonus programs, market/economic cycles, and weather events result in deferral of critical maintenance activities that impact asset performance, service life, and cost of ownership. The resulting asset depletion costs and financial and operational costs are slowly (and too quietly) absorbed until some emergency outage or event dictates costly emergency reaction to repair/replace the systems.

This case study describes how a large municipal water department combined strategic vision with a proactive management initiative to develop and implement a comprehensive asset management plan for $24.3 million in HVAC and roofing systems on 243 buildings at 42 sites. The program included detailed man-hour utilization and scheduling analysis to determine long-term staffing levels needed to support and execute the maintenance inspection and repair activities that are critical to reliable system performance and service life. The initiative included detailed asset inventory and condition assessment migrated into a management-planning tool that communicates with the department’s computerized maintenance management systems (CMMS) and financial planning systems.

The case study will demonstrate how accurate condition assessments and predictive maintenance planning can be implemented using existing district software tools to build and manage an effective asset management solution. The project involves roof system and HVAC system asset quantification, condition prioritization, and five-year preventative maintenance programming on 243 buildings with 473 roof sections and 2,604 HVAC unit components. The program planning, condition assessment, and database development work was performed during Year 1 of the program.

The component condition priorities and budget planning data were assimilated into a nonproprietary database tool, which is interactive with the district’s CMMS maintenance planning and work order control system. Utilizing the component condition ratings, component/system type, and prioritization data, the district was able to competitively bid and efficiently manage the high-priority repair/replacement project on 191 buildings during Year 2 of the program.

The system information allowed development of this large replacement and repair project that enhanced contractor participation, reduced remediation project cost (8.2% under budget), and reduced project design and contract management costs (3.2% of construction cost).

CASE STUDY

This paper analyzes how accurate quantification and prioritization of building system assets can provide the information required to effectively maintain and schedule/control capital replacement of key building components using a systematic approach. A proactive approach serves to improve the roof/HVAC system selection process and the life cycle of plant assets to defer replacement capital costs. The primary objectives for these assessments and management programs include:

1. Identify and create awareness of plant asset depletion rates and need, and proactively meet those needs. (Planned maintenance programs utilize global assessment with common criteria and life cycle forecasts to develop proactive maintenance procedures.)
2. Establish criteria to demand, design, and deliver effective maintenance programs and projects. (Proactive scheduled maintenance procedures address component needs to manage depletion rates to extend asset’s reliable service life.)
3. Incorporate design details and construction plans to protect operations and financial plans. (Accurate need-based annual project plans allow packaging of projects to realize project cost savings from procurement leveraging, economies of scale, and streamlined project management.)
4. Apply life cycle and financial analysis to the building envelope. (Long-term asset performance demands quality system design, details, and construction with timely maintenance procedures.)

A large municipal water utilities district (“the District”) faced many operational, tactical, and strategic challenges in managing the existing assets, including, but not limited to, the following:

1. Aging buildings infrastructure system
2. Variable plant assets (building types/needs) for water, wastewater, and pumping divisions
3. Population growth and resulting capital demand
4. Widespread facility and building assets due to water source and customer service market
5. Constrained budgets and deferred maintenance culture/history
6. Bureaucratic management structure with poor maintenance/repairs, and asset replacement plan
7. Multiple disconnected management software systems
METHODOLOGY

Conley Group was engaged by the District to develop an asset management plan for roofing and HVAC systems. The District serves 31 suburban cities and over 3.8 million customers with aging plant and infrastructure assets, which include three freshwater treatment plants, two wastewater treatment plants, and 42 pumping facilities to bring raw water to the plants and provide treated water to their customer base, along with 70 administrative service centers and support facilities.

The District’s stated goals were to significantly improve the efficiency of its current maintenance programs, reduce the number and severity of roof leakage/ HVAC outage events, extend the service life of plant assets, and develop a systematic approach to capital asset planning and replacement. The engagement included:

- Survey and assessment planning
- Asset surveys
- Needs-based condition information with priorities, schedules, and budget cost estimates
- Prioritization and five-year annual operations plan
- Program management
- Asset program coordination with district-directed services and systems

The initial program scope included a plan for 232 buildings. Roof assets on the designated buildings included 452 roof sections and 1.4 million square feet of area with nine different roof system types. HVAC system assets included approximately 2,604 units, which included air handlers, boilers, chillers, cooling towers, DX split systems, fans, heating coils, package DX units, unit heaters, and volume control units ranging in age/technology from new to more than 35 years. Although the HVAC equipment assessment and programming represented a significant component of the work scope under this engagement, this case study and presentation will focus on the roof system assets and the systematic approach used for program planning and asset condition assessment to build a functional program to meet the District’s goals and needs.

The District-provided resources/documents included an electronic library with a partial listing of as-built data and available drawings. Their building data and limited record drawings had been indexed in a 22,000-line spreadsheet, which complicated sorting, use, and historical research of the data. Typically, limited historical data for roof system warranties, roof system maintenance, and roof leak history were provided. The District required that the database be delivered in Microsoft Access-based, PC/web-linked, tablet-compatible format. The
District provided a shell data platform that included building names, addresses, and limited building information. Conley Group was charged with developing and customizing the shell database program to accomplish the District’s objectives.

**SURVEY AND ASSESSMENT PLANNING**

A detailed logistical schedule was developed using six two-man survey teams to conduct both the roofing and HVAC system assessments. Schedule considerations included access to 42 secured sites, many at remote locations that are geographically scattered across a 4,310-square-mile area covering parts of six counties (Figure 1). After four weeks of planning, research, and pilot project training, the field assessment was completed over an eight-week survey schedule. An additional 11 buildings (243 total) were added to the initial inventory in Year 2. Customized HVAC and roofing survey inspection and data collection templates were developed to collect program-specific data.

Roof system assessment personnel were selected using Registered Roof Observers with prior experience on large-scale roof assessment surveys serving as team leaders. Each roof area was accessed and inspected (cored where applicable) to assess the construction and general condition of the roof system and to identify and quantify flashing and membrane defects. The District’s protocols stipulated that a Condition Priority Index Scale of 1 to 5 be utilized to prioritize the roof areas by need and estimated service life remaining. The asset Condition Priority Index Scale for this program was finalized with the District’s input as follows:

1. Critical (immediate replacement required)
2. Potentially critical (replace within one year)
3. Necessary/not yet critical (replace within 2 - 5 years)
4. Recommended (replace in 6 to 10 years)
5. No remedial action required at this time

**ASSET SURVEY**

Roof areas were visually inspected, penetrations mapped, photographed, measured, and cored (where needed) to help determine roof system condition and verify roof system construction. Along with the roof inspection and cores, a visual inspection of the underside of the exposed roof deck was performed to verify deck type, direction, and condition. On-site personnel were interviewed to ascertain existing leak conditions.

The exterior wall systems of personnel-occupied office and lab buildings were scanned using thermographic imaging systems to determine where significant insulation or air loss was observed that could be contributing to HVAC performance and high energy use costs. Infrared thermograms of the exterior wall anomalies were included in the HVAC database for further analysis.

**DATABASE DEVELOPMENT**

Database development, data QA/QC, and upload were sequenced with field assessment to transform the Microsoft Access shell to meet the District’s requirements. Continuous upgrade of the database architecture, data screens, and graphic user interface (GUI) were implemented with improvements to GUIs evolved from brainstorming sessions between the assessment team and the District’s MIS representatives to accelerate data access and screen lag. Customized conventions such as GPS fly-in, roof area navigation coordinates, hyperlinks, and naming conventions for integration with the District’s CMMS work order system were incorporated. In addition, custom roof defect data tables were developed to simplify and enhance data search and use. These features were implemented as “earth-friendly” enhancements to reduce the need for traveling to sites and printing reports.

**DATA ENTRY**

Collected roof survey data was entered via a Roof Condition Survey matrix that houses the primary building data for each building. A facility photo and navigable roof plan are included, along with a GPS link to Google Earth Pro to enable database users to “fly in” to each building and roof section via prelinked longitude and latitude coordinates and key plans. Building and roof area data and related quantities are displayed for quick access to key information for each building (Figure 2).

Survey data collected for each roof section are accessed via the roof section survey tabs within the primary database structure. Linked data tables were developed to house the roof section data. Linked data tables included:

- General info/photo
- Roof system type
- Leaks/drainage
- Warranties
- Core sample/asbestos info/other
- Roof assembly construction
- Roof defects and quantities
- Rooftop penetrations and details
- Capital and expense budgets
- Comments

The Roof Section Survey Data tab allows users to quickly sort/isolate specific asset information housed within the various data

![Figure 2 – Sample database input screen.](image-url)
Information specific to individual roof sections (roof section size, condition priority index, service life, and other attributes) can be accessed via pull-down menus/tabs.

Over 10,800 photos were catalogued and downloaded to link to each specific roof area. Photos were right-sized/compressed to mitigate file size and accelerate access/processing times throughout the database.

Continuous quality control review was conducted to ensure that accurate data and photos are correctly linked to each building and roof sections. Systemic periodic reviews were performed by the QA/QC team, consisting of the project manager, project representatives, and database QA/QC manager to validate accurate data entry and database/screen/report development.

Detailed AutoCAD roof plans were created and incorporated into the database from field survey drawings. Dimensions, details, and roof defects (membrane and flashing) were located on the plans for inclusion into the database. Systematic periodic quality control of dimensions, details, and roof defects was performed by the QA team to ensure accuracy of the roof plans. Accurate roof drawings are critical for roof defect repair and for planned roof replacement projects.

**REPORTS**

A number of customized District-required reports were developed for use, including:

- Individual Building Report
- Comprehensive Building Report
- Defect Report with Repair Recommendations
- Annual Expense Report
- Capital Replacement Report
- Executive Summary
- Best Practices Guideline Manual (maintenance manual)

Additional reports were developed by the database development team to enhance the access to and use of data by the District’s staff. Additional custom reports included:

- Comprehensive Facility List Report
- Print Roof Plan (hyperlink)
- Warranty Query
- Repair vs. Replacement Cost Query

**DATABASE ROLLOUT AND TRAINING**

The database rollout and training phase was scheduled at the completion of database development, data entry, quality control, and custom report development. Training was conducted with the District’s staff to facilitate understanding, navigation, and use of the database to support program operations and management. Various reports and data were reviewed and analyzed and adjusted to improve functionality. The reports and data were sorted to create Priority 1 and Priority 2 Needs Lists that identified 19 buildings with roof sections needing near-term replacement and 172 buildings with high-priority roof defects needing repairs.

Based upon the condition data and priorities, the District funded $1.535 million for replacement design and construction of the 19 high-priority buildings and $1.262 million in construction expense funds for roof defect repairs on 172 buildings. The project delivery approach employed a bundled design/bid/build plan that resulted in one contract award that was delivered in Year 3 with construction and project management cost savings as discussed herein.

**PROGRAM MANAGEMENT – ROOF DESIGN AND REPLACEMENT, ROOF DEFECT REPAIRS**

Phase 3 of the program management provided funding for roof replacements and repairs for the roof systems identified with a Priority 1 or 2 Priority Condition Index (PCI). (See Figure 4.) Defect repairs for the high-

**Figure 3 – Sample capital and expense budgets.**

**Figure 4 – Before and after roof replacement.**
priority buildings in the roof asset inventory were included in the scope of work to address current leaks and to perform repairs critical to extending the life cycle of the roof assets.

Comprehensive contract documents and an invitation for bids (IFB) set of roof plans, roof details, and specifications were prepared for bidding the project. Conley Group assisted the District with design, bidding, bid tabulation, and contractor selection. In addition to the roof replacement work on 19 buildings, specified quantities of Priority 1 and 2 roof defect repairs were performed on 172 buildings with 319 roof sections. Defect repair quantities were scheduled based on survey data collected and extracted from the database. A total of 19 buildings with 45 root areas and 98,801 sq. ft of roof membrane were replaced under this contract. The completion of this work served to correct chronic leak conditions and to address deterioration conditions on the most critical roof areas of the building inventory.

Conley Group’s team supported the District’s procurement team to competitively bid and award a single repair contract in the amount of $2.62 million for the specified replacement and defect/maintenance repairs. The repair and replacement work was completed in nine months with $108,300 savings under budget (Figure 5). The high-priority roof replacement and repair project served to address current and near-term leak risks and to perform needed repairs to protect roof assets and extend expected service life. The Microsoft Access database and District’s maintenance work order systems were updated to reflect the repairs and maintenance inspections.

**BEST-PRACTICES GUIDELINE**

Roof membrane and flashing defects were identified and quantified during the asset survey on each roof section. Defect data were collected using the customized roof inspection templates. Specific condition defect codes were assigned to each defect type, and a corresponding method of repair was developed for inclusion in a Best Practices Guideline Manual (roof maintenance manual). Defect repair methods are critical to protect existing roof assets on roof sections that were not being replaced during this initial phase. The defect repair methods also provided instruction for repairs required during the planned roof maintenance program. Roof defect quantities, location, and severity priorities were uploaded into the database, which allowed for quick access to defect quantity repair planning and cost information. A comprehensive repair and maintenance plan was prepared with repair procedures for each type of membrane and flashing defect. The roof maintenance manual and plan were used to bid high-priority defect repairs in conjunction with the initial phase of roof replacement work.

**ROOF MAINTENANCE PROGRAM**

A proactive preventative maintenance plan was implemented during the construction of the critical roof replacements and roof defect repairs. The program consists of periodic roof system inspections on each roof section during each 12- to 24-month period, and included provisions for inspection, debris removal, drainage component clearing, defect repairs, moisture scans, and emergency leak response. The scope of work for the maintenance plan included inspection and a prompt feedback/update loop of the condition of the roof system components on each roof area. Preventative maintenance inspection tasks include:

1. Inspect roof system components—roof membrane, membrane flashings, sheet metal details (roof edge, copings, counter-flashings, etc.), penetrations, expansion joints (roof and rise wall), and roof-mounted equipment (HVAC, gas pipe, and conduits) for signs of leaks, deterioration, or damage on all roof sections. Record, locate, and photo-document conditions.
2. Inspect wall claddings adjacent to roof sections (brick, stucco, EIFS, metal, etc.), expansion and control joints, and openings (windows and doors). Record and photo-document conditions.
3. Remove all debris and trash from roof.
4. Inspect and clear drainage systems of debris (drains, gutters, and downspouts).
5. Perform basic repairs at penetrations and perimeter flashing details per maintenance manual.
6. Notify District of repairs required that exceed basic maintenance.
7. Record and photo-document potential warranty claims.
8. Update Roof Asset Program database and plans with updated inspection, defect, and repair data.

Currently, Priority 3 and 4 defect and preventative maintenance repairs for 1,132 HVAC system elements (Figure 6) on 142 buildings and for 96 roof sections on 42 buildings are being programmed and funded. Roof asset database queries were used to identify the recommended maintenance repairs/budget and sort the work by facility group, geographic region, and by building and roof area. Conley Group assisted the District’s management team to utilize the database to confirm required defect and preventative maintenance work scopes and quantities to prepare 2016 repair budgets.
The final component of the engagement included selecting, procuring, setting up, and launching a capital planning and work order database. Across the physical plant inventory, the District originally had six different work order systems in use by various departments. Common issues included need for integration and compatibility between the systems, cost, functionality, and ease of use. Two of the service units had deployed an internet-based software (NetFacilities), which was evaluated and ultimately selected based on functionality, ease of use, and cost. Facility, building, and asset data (roof areas and HVAC components) were extracted from the Microsoft Access database tables into specially formatted spreadsheets to load the data into the NetFacilities program. Special naming conventions using Microsoft Access queries were developed to identify/link the individual roof sections and HVAC components to communicate with the NetFacilities program, and cross-referenced to the forms in the Access databases for easy identification. Preventative maintenance tasks and maintenance frequencies were developed for asset type to be able to create work orders to service the assets. The NetFacilities system included provisions for both preventative (reoccurring) and corrective repair work orders, and contained key reporting features and a cell phone module to allow access to the system from the field.

Beta testing followed data migration into the program to verify functionality and to allow the District to begin training on use of the program. The software manufacturer and Conley Group teamed to provide training for the District to facilitate program roll-out. Program launch initially focused on the roof system maintenance procedures; the HVAC maintenance program will launch in 2016. The launch of the Roof Maintenance Program marked the beginning of routine, systematic maintenance of plant assets and propelled the District toward the goal of maintaining and extending the life cycle of their assets.

**PROGRAM TIMELINE**

The program timeline was developed as follows:

- Survey and assessment planning – July 2012
- Asset survey – August - November 2012
  — Assessment report with cost estimates and prioritization – December 2012 - March 2013
- Phase 1 – Roof repair and replacement project – June 2013 - August 2014
- District-directed MIS integration services – August 2013 - February 2014
- Program management – Ongoing since 2013

**DISTRICT-DIRECTED SERVICES – FACILITIES CAPITAL PLANNING AND WORK ORDER DATABASE INTEGRATION**

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**Figure 6 – HVAC equipment type totals by facility.**