Asbestos Abatement for Business Owners:

Identifying a Least-Cost Approach

Nathan Biasotti

Oregon State University

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Abstract

Building managers may need to develop an asbestos abatement plan, because asbestos poses a human health risk and is commonly found in buildings built prior to 1980. The current study examined four different scenarios: operations and maintenance (O&M) program only, removal, enclosure, and encapsulation. All scenarios were evaluated at various intervals over 50 years with a discount rate of 4.5%. It was hypothesized that the least-cost approach would to be to defer abatement to renovation or demolition. Calculations for each scenario were estimated using previous research done in the area of abatement, and then adjusted for inflation. It was found that if asbestos was non-disturbed and could remain in place indefinitely, the least-cost approach for asbestos abatement at various intervals over 50 years was an O&M program. If not feasible, removal during renovation or demolition was the next least-cost approach, which supported the hypothesis. Enclosure and encapsulation at present time followed later by renovation or demolition was found to result in the highest cost. A 1% sensitivity analysis resulted in increased costs when abatement was deferred. These results provide valuable insights to building managers that need to identify least-cost asbestos abatement options.

This topic was chosen for the study because of the relevance it has in my career. I am currently employed through Union Pacific (UP) Railroad and wanted to use this research topic as an opportunity to gain knowledge about asbestos containing materials (ACM). Currently, UP is involved with many ACM abatement projects and decisions need to be made regularly regarding the least-cost approach. This project taught me that there is enormous complexity regarding asbestos abatement, and there is not a one-size-fits-all approach.

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Asbestos containing materials (ACM) are used in a wide variety of building applications such as ceilings, insulation, and floor tiles. Asbestos has many beneficial properties including fire resistance, chemical resistance, and strength that make it highly demanded for building construction. According to Azen (1992), there was moderate asbestos usage before 1945, but its peak usage was between 1945 and 1975. As time went on, asbestos was identified to potentially cause respiratory diseases including asbestosis, mesothelioma, and lung cancer. Most of the reported disease cases were occupational, resulting from high exposure to workers in the asbestos manufacturing or installation industry. After 1975, federal regulations were enacted that banned some asbestos products, their installation, and set worker health standards.

Although there are health hazards from asbestos, some ACM can still be installed in new buildings. Currently, there are no regulations that require the removal of asbestos just because of its presence. Many buildings still contain ACM and according to the same study done by Azen (1992), of 207 public buildings sampled in the study, 80% contained ACM. However, breathing in airborne asbestos fibers is a health concern. The condition of ACM and the likelihood of disturbance determines if airborne asbestos fibers are likely to be released. Health risks depend on the amount and duration of exposure to asbestos fibers. According to Lange (2005), the likelihood of disease is correlated with high-long term exposure. Additionally, asbestos abatement is costly due to regulations for containment, worker protection, and disposal. Thus, it is not obvious whether the benefits of asbestos removal outweigh the costs and what the least-cost approach to asbestos abatement is under various circumstances. The type of asbestos, its condition, location, probability of disturbance, and timing of abatement are all critical factors in making an abatement decision. Asbestos abatement options include maintaining it in place, removal, enclosure, encapsulation, or a combination over the lifetime of the building. Knowing whether asbestos should be abated and the least-cost approach to achieve it could save building owners or businesses thousands, if not millions of dollars, in forgone abatement costs. In recent studies, it has been shown that in most cases, airborne asbestos fiber levels in buildings are too low to cause health concerns, and health risks were overestimated due to past occupational exposure.

The current study provides knowledge about the factors to consider when deciding whether asbestos should be removed and how to identify the least-cost approach for asbestos removal under various circumstances. Specifically, various approaches to abatement are analyzed, as well as their costs, to develop a least-cost approach. In the next sections, we cover conditions, regulations, health hazards, abatement options, and cost considerations, all of which play a crucial role in identifying the least-cost approach.

Literature Review

Friability and Condition of ACM

The most important factor for determining whether asbestos should be removed and the least-cost approach to removal is the possibility of human exposure to airborne asbestos fibers. This is due to the friability, condition, and likelihood of disturbance. Friable is defined as easily crumbled. In terms of ACM, it means ACM can be reduced to powder easily by hand pressure or disturbance. Disturbance can result from physical contact, mechanical vibration, or from an air plenum blowing on the ACM. ACM becomes a concern when it has physical damage, water damage, or has deteriorated. Additionally, the friability, condition, and possibility of disturbance are all important factors for determining if ACM poses a health risk. Fortunately, this can be determined by hiring a qualified asbestos inspector to complete a thorough building survey. According to the Environmental Protection Agency (EPA) (1985), ACM can be described as one of three types: surfacing materials, thermal system installation, or miscellaneous materials. Surfacing materials include fireproofing or acoustical ceilings that have been sprayed on or troweled. Thermal system insulation (TSI) is a wrapped insulation around pipes and heating equipment. The greatest hazard results from surfacing materials and thermal system insulation, because they can become friable and when disturbed, release airborne asbestos fibers. The EPA recommends immediate removal of TSI and surfacing materials when in poor condition. Miscellaneous materials include all other ACM such as floor tiles, roofing shingles, mastics, wall boards, and others. Miscellaneous materials are generally non-friable and not much of a concern. According to the Jet Propulsion Laboratory and California Institute of Technology (1990), non-friable materials are "matrix bonded composite products" and so the asbestos fibers are tightly bound as well. Under normal conditions, they do not present a hazard to health. However, disturbance is possible if the material is drilled, sanded, or disturbed by other mechanical means.

Environmental Regulations

According to the Environmental Information Association (EIA), the primary federal regulatory agencies involved with asbestos are the EPA and the Occupational Safety and Health Administration (OSHA). EPA regulations are designed to protect the public and environment, while OSHA regulations are designed to protect asbestos workers and building occupants. The National Emission Standards for Hazardous Air Pollutants (NESHAP) was enacted by the EPA and sets requirements for demolition/renovation, reporting, and waste. NESHAP places ACM into three categories based on friability. *Category 1* is non-friable packings, gaskets, resilient floor covering, and asphalt roofing in good condition containing more than 1% asbestos. *Category 2* is all other non-friable ACM in good condition containing more than 1% asbestos. *Category 3* is Regulated Asbestos Containing Material (RACM), which is friable ACM containing more than 1% asbestos. Additionally, RACM also includes *Category 1 and 2* ACM which has become friable or may become friable due to mechanical disturbance or damage during renovation or demolition. NESHAP requires a building survey to be completed prior to work that may disturb ACM. The threshold for NESHAP to kick in occurs when 160 square feet, 260 linear feet, or 35 cubic meters of RACM is disturbed. RACM over this amount is required under NESHAP to be removed prior to building renovation or demolition. Notifications to the EPA regional and/or state office is required in advance for any demolition activity, or if threshold RACM is disturbed during renovation. During removal, wet methods such as spraying ACM down with a chemical solution are required to help reduce dust, unless otherwise approved by the EPA. No visible emissions of dust are allowed at any time during removal, transportation, and disposal of ACM. NESHAP requirements for ACM waste disposal include shipment records, packaging requirements, and drop off at approved landfills.

OSHA regulations are designed to protect workers who disturb ACM as well as building occupants adjacent to the disturbance. According to the EIA, permissible airborne exposure limits are established by OSHA as an 8 hour weighted average of 0.1 fibers per cubic centimeter (f/cc) or a short duration exposure limit 1.0 f/cc in 30 minutes. Personal air sampling is required when ACM is disturbed. If exposure limits are exceeded or the employer does not have personal air sampling devices, certain worker protection such as respirators, gloves, suits, etc. are required depending on the ACM and task. OSHA requires specific worker training, work practices, and containment depending on the type of material and scope of work. Friable surfacing material and TSI removal requires extensive job site preparation including negative pressure enclosures, worker decontamination, and respiratory protection. OSHA requires building owners to either complete an asbestos survey of the building, or assume that surfacing materials and TSI prior to 1980 contain asbestos and communicate this information to those at the worksite. OSHA standards apply to all types of work and situations involving asbestos including removal, repair, encapsulation, installation, transportation, and housekeeping activities. It is important that building owners become familiar with OSHA regulations because any in-house work performed on ACM is regulated. Additionally, depending on the task, certain worker protection, worker training and/or certification, as well as reporting requirements may be required.

The regulations that were described are the minimum federal requirements that must be followed under the supremacy clause. State and local governments have the ability to be more stringent than the federal requirements. Therefore, every state, city, or county can have different requirements that apply to ACM, and building owners must contact their state and/or local asbestos program managers to verify compliance with all applicable laws.

Health Hazard Concerns in Buildings

There have been many studies conducted to determine if health risks exist in buildings with ACM, and most have shown little to no risk when ACM is undisturbed. According to Dewees (1986), the reason for the current concern is due to asbestos insulation and manufacturing workers who were exposed at high levels for many years. As time went on, many of the workers were diagnosed with asbestos related diseases such as mesothelioma, asbestosis, and lung cancer. Dewees also concluded that ACM exposure to building occupants that was in good condition and undisturbed, was extremely low and only “one one-thousandth to one ten-thousandth the exposure facing insulation workers” (Dewees, 1986). Using disease models, no significant risk of asbestosis for building occupants was found. Under all scenarios, asbestos removal was a very expensive way to reduce the risk of mortality. It was concluded that with the same expenditure on asbestos abatement, many more lives could be saved by investing into other occupational safety programs. Additionally, these findings are supported by statements from the EPA in their building owners guide produced in 1990. They determined that the average airborne asbestos levels in buildings was low and the risk to occupants was very low (Environmental Protection Agency, 1990). At low exposure levels they found the risk to be negligible or zero. The EPA also noted that if abatement is not completed correctly, airborne asbestos levels can be higher *after* abatement than before abatement. In the largest airborne asbestos building study to date, Lee and Van Orden (2007) analyzed air samples of 752 buildings with ACM. Their findings indicated that undisturbed ACM in buildings did not cause elevated airborne asbestos to approach regulatory levels. They found that even if asbestos fibers were released by maintenance, falling or dislodging, average building concentrations did not substantially increase. The average concentrations were found to be 1000 times less than regulatory levels. Additionally, the study discussed that even the regulatory levels were below any level known to cause disease. Mentioned in this same study, of 49 buildings sampled in 5 cities, it was found that the air in some public buildings with ACM was no different than outside air. Nonetheless, there is one thing that all the literature agrees on and that is if ACM is friable and disturbed, a hazard exists from airborne asbestos fibers. Dewees (1986) mentioned that exposure was likely for those who work around ACM that was damaged and who disturb it during work activities.

Abatement Options

Recognized asbestos abatement options by the EPA include managing in place, encapsulation, enclosure, and removal. All abatement options first require a thorough building survey to locate and document all ACM. Managing asbestos in place involves the creation of an Operations and Maintenance program (O&M) to monitor ACM in order to reduce the chance of ACM disturbance. According to the EPA (1990), in some cases an O&M program can be more appropriate than removal. An O&M program should be overseen by an appointed asbestos program manager at the business. All work done on a building should first be approved by the O&M program manager to ensure no ACM will be disturbed. Additionally, periodic inspections should be conducted to ensure in place ACM has not deteriorated. Any ACM that is found to be a hazard during periodic inspections should be abated by one of the other options.

Encapsulation involves spraying ACM with a protective sealant in order to strengthen it and reduce the likelihood of fiber release. However, encapsulation has limitations. According to the EIA, it should only be used on thin, friable ACM that is in good condition. Additionally, the EPA recommends only encapsulating acoustical plaster that is in good condition. If ACM is in poor condition or it is very soft, encapsulation is not recommended because it may further damage the ACM with the addition of the added weight. When encapsulating ACM, building containment and worker protection is required. Encapsulation requires an O&M program to be continued while the ACM remains in place. Encapsulated ACM will still need to be removed before renovation or demolition per NESHAP.

Enclosure involves construction of airtight barriers such as walls and ceilings around ACM. Enclosure also has limitations, the ACM needs to be isolated in distinct areas. Any ACM that is damaged should be repaired before enclosing. When enclosing ACM, building containment and worker protection is required. An O&M program must be continued to check the enclosure for damage for the life of the building. Enclosed ACM will also need to be removed before renovation or demolition per NESHAP.

Removal is the only permanent abatement solution. Removal involves extensive job site preparation, containment, and worker protection. After ACM is removed, an O&M program is no longer needed and no ACM will need to be removed prior to building renovation or demolition. Replacement materials will need to be installed after ACM is removed. In research done by Ross (1997), a removal option for thermal system insulation was with the use of glove bags. Glove bags go around pipes to seal them, while also allowing workers to remove the ACM inside through hand holes. Glove bags can also be used on other materials if the glove bag completely encloses the material. Extensive containment and negative pressure enclosures are not needed with glove bags.

Abatement Decisions

The EPA created assessment tables for surfacing materials and thermal system insulation. Building owners can use the tables to determine how and when abatement should be done. To summarize, the table for surfacing materials specifies that ACM in good condition with a low chance of disturbance can utilize an O&M program, while ACM in poor condition needs to be removed as soon as possible. If surfacing materials are in good condition but have a high chance of disturbance then removal, encapsulation, or enclosure should be completed during the next building renovation. Additionally, the table for thermal system insulation has similar specifications. The surfacing materials table can be found in Appendix A, and the thermal system insulation can be found in Appendix B.

Cost Considerations

In studies performed by Dewees (1986), substantial savings were found when abatement was deferred for ACM in good condition. Additionally, as previous research has suggested, there was little benefit from abatement when ACM was in good condition. ACM removal right before demolition was found to be less expensive than other removal options, because there were no costs associated with occupant disturbance, building protection, and re-installation. It was also found that enclosure and encapsulation were less expensive than removal but did add an additional cost before renovation or demolition. It was suggested that two costs need to be considered to identify the least-cost approach for asbestos abatement: the direct cost of abating the ACM, and the indirect cost of dislocating occupants and loss of productivity from the abatement process. In his study of friable ACM, Dewees (1986) calculated the price per square foot of both direct and indirect costs associated with abatement. The table can be found in Appendix C.

According to a report by Friedman (1994), one should choose between an O&M program or abatement of ACM in good condition by comparing the short and long-term costs of both options. It was also suggested that while completing partial abatement, it may be wise to abate other materials at the same time, since it will cost less and be quicker than another project in the future. Additionally, it was found that the present value of a typical O&M program with initial cleanup was less expensive than near-term removal. Banks (1991), reported the costs of O&M program versus removal costs for a typical office building with asbestos containing fireproofing insulation. The cost of an O&M program was found to be 17.2 cents/square foot/year. The equivalent O&M cost in removal terms was $3.03/square foot. Removal costs of fireproofing were found to range from $15-25/square foot. The fireproofing removal cost was well above the

O&M equivalent of $3.03/square foot. It was concluded that considering cost alone, removal at the present was not justified. This was supported by the EPA (1990), which recommended that an O&M program is a less expensive alternative to removal. The EPA recommended that building owners compare the cost of immediate removal to phased removal with O&M, and removal before demolition with lifetime O&M. Dewees (1986) noted that if ACM was often disturbed, the price of an O&M program may increase drastically due to having to clean up disturbances.

The EIA (2015) also expressed some cost considerations for building owners. They noted that the cost of initial removal was most always higher than the cost of an O&M program, but in the long-term, ACM had to be removed before demolition. Therefore, removal at present may be less expensive. The EPA (1990) made a similar recommendation, concluding that with both enclosure and encapsulation the initial costs will likely be lower than removal, but the long-term cost may be higher. The EIA also agreed with prior findings that abatement costs could be reduced if performed during renovation or demolition.

A journal article by Ross (1997), highlighted the value of glove bags used during abatement. When glove bags were used, there was the potential to save building owners money. This was due to the fact that abatement workers could safely remove ACM quicker and without the need for costly, large negative pressure enclosures. Glove bags are also recommended by the EPA and EIA.

PROJECT STATEMENT

Deciding if asbestos abatement is necessary, as well the least-cost approach to abatement, can be particularly challenging questions for business owners. Asbestos is a carcinogenic fiber with the potential to become airborne, which can pose significant human health risks. However, asbestos removal can be very expensive due to environmental and worker safety regulations, as well as any and all costs associated with interrupting business operations. Therefore, it would not be a wise decision to remove ACM immediately if there was no health risk. However, according to NESHAP regulations, even if ACM was not removed now, it would eventually have to be removed prior to disturbance due to renovation or building demolition. Understanding the costs that are involved in these situations will help building owners make more informed decisions regarding ACM abatement. Therefore, the goal of this study is to identify any potential cost-saving measures and procedures that a business can utilize when making asbestos abatement decisions. Specifically, this study will address the following research question: "What is the least-cost approach to asbestos abatement for a business?" To address this question, qualitative as well as quantitative research will be conducted on the different types of ACM and asbestos abatement options. Applicable regulations and laws will be highlighted as they pertain to asbestos abatement decisions.

APPROACH

The current study will utilize cost data from the literature review to calculate costs of different abatement options at various intervals over 50 years. The abatement options include maintaining in place with an O&M program, removal, enclosure, and encapsulation. The sample building for this study will be a 1,000 square foot office building with 1,000 square feet of friable asbestos containing ceiling insulation. The data on cost for friable insulation abatement can be found in Appendix C. To simplify costs for the data analysis, cost ranges that are listed in Appendix C as both low and high will be averaged. Costs were adjusted for inflation according to the following equation: ***1985 Price x (2017 CPI / 1985 CPI) = 2017 Price*** -or- ***1985 Price x (244.5/107.6) = 2017 Price***. This study discounted future costs to present value terms.

Discounting reflects the opportunity cost to the business, in terms of what yield it could receive by not spending funds at the present. The discount rate used for this study was 4.5%. This discount rate was chosen because it is assumed business owners are in the private sector, so the opportunity cost should reflect the marginal rate of return on private investment. According to Boardman, Greenberg, Vining, and Weimer (2011), the best estimate of this value is the real, before-tax rate of return on corporate bonds, which is approximately 4.5% (Boardman, Greenberg, Vining, & Weimer, 2011). Any abatement cost occurring in year *t* was discounted to the present value using the following equation: $\boldsymbol{Present\ Value = \frac{Cost}{(1.045)^t}}$

As discussed previously, the O&M cost was found to cost 17.2 cents per square foot in 1990. Adjusting for inflation, the cost is 32 cents per square foot. For a 1,000 square foot building the yearly O&M cost is $320. Since the O&M cost occurs every year, to calculate the present value of total cost in *t* years the following equation is used: $\boldsymbol{Present\ Value = 320\ x\ \frac{1-(1.045)^{-t}}{0.045}}$. For any scenario where abatement is deferred to year *t*, the cumulative cost of the O&M program is added.

If removal is performed during times other than renovation or removal, building owners face the full cost of removal, disposal, and replacement as well as costs associated with dislocating workers. The costs associated with dislocating workers can be found in Appendix C and include moving, alternate space, and lost productivity. For a two-way move, moving costs of varying distances adjusted for inflation, were found to cost $1.71 per square foot. Alternate space rental will be assumed to be needed for two months and adjusted for inflation, the price was $5.69 per square foot. Lost employee productivity due to moving to alternate space will be assumed at approximately 7 days lost or 1/50th of the average yearly wage. Average wage will be assumed at $50,000. This is calculated at ***average yearly wage x 0.02*** -or- ***50,000 x 0.02= $1,000*** per employee. It will be assumed that an employee takes up 200 square feet of floor space, so for a 1,000 square foot office building there will be 5 employees at a cost of $5,000 in lost productivity. Encapsulation and enclosure on their own also include the costs of dislocating workers.

If abatement is deferred until renovation, the employees will already be moved out due to the planned renovations, so the only additional asbestos abatement related cost will be one additional month of alternate space at $2.85 per square foot. If removal is deferred until demolition, the only costs are for ACM removal and disposal. No additional costs are incurred.

Encapsulation and enclosure are temporary options, meaning the ACM must still be removed prior to renovation or demolition. In this situation, the cost of encapsulation or enclosure is taken initially and then at a later date, the full cost of removal at renovation or demolition is added on to form the grand total.

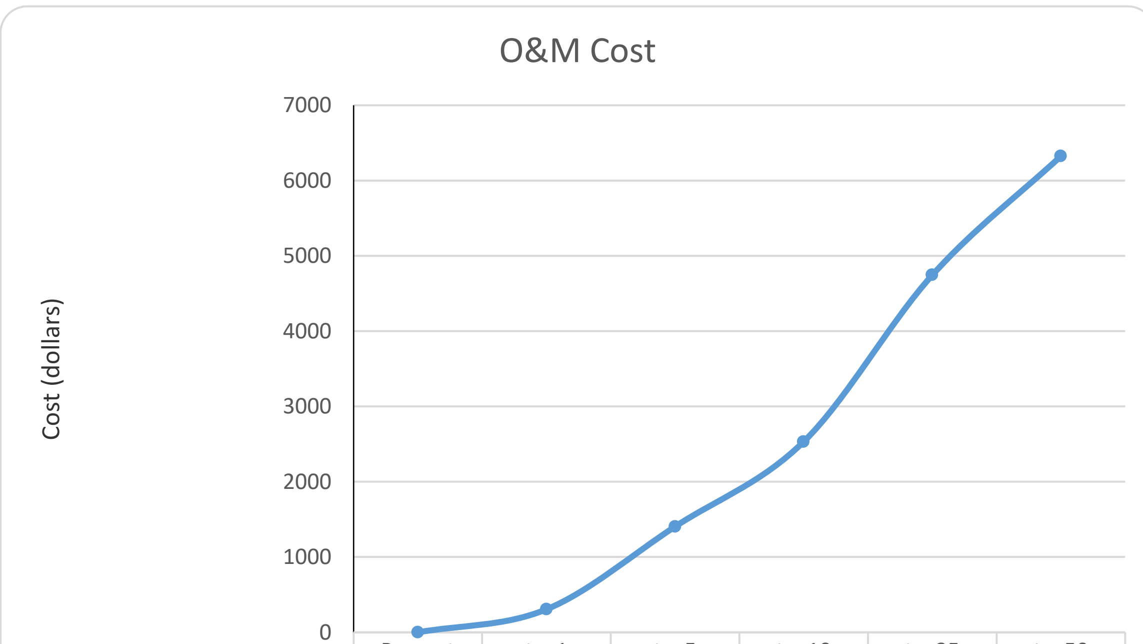
A sensitivity analysis will be performed on removal costs to see if present value rises or falls when the cost of a continued O&M program is added. Sensitivity will be calculated at both a 1% and 7% discount rate.

Results

The hypothesis for the current study was that the least-cost approach for asbestos abatement decisions would be to defer abatement to renovation or demolition. The results indicated that if asbestos was non-disturbed and could remain in place indefinitely, the least-cost approach for asbestos abatement at various intervals over 50 years was an O&M program. If not feasible, results indicated that the next least-cost approach was to defer abatement to renovation or demolition, thus supporting the original hypothesis. The following four scenarios illustrate possible abatement options for office buildings. In the spirit of ceteris paribus analysis, the square footage of the building and ACM in each scenario is held constant at 1,000 square feet.

Scenario #1: O&M Program Only

Chart 1 presents the cost of an O&M program at various intervals over 50 years. To predict O&M costs, we follow Banks' (1991) findings for office buildings. The multiplier used to predict the O&M costs was $0.32 per square foot per year after adjusting for inflation. The O&M cost per year was calculated to be $320 and discounted to the present value.

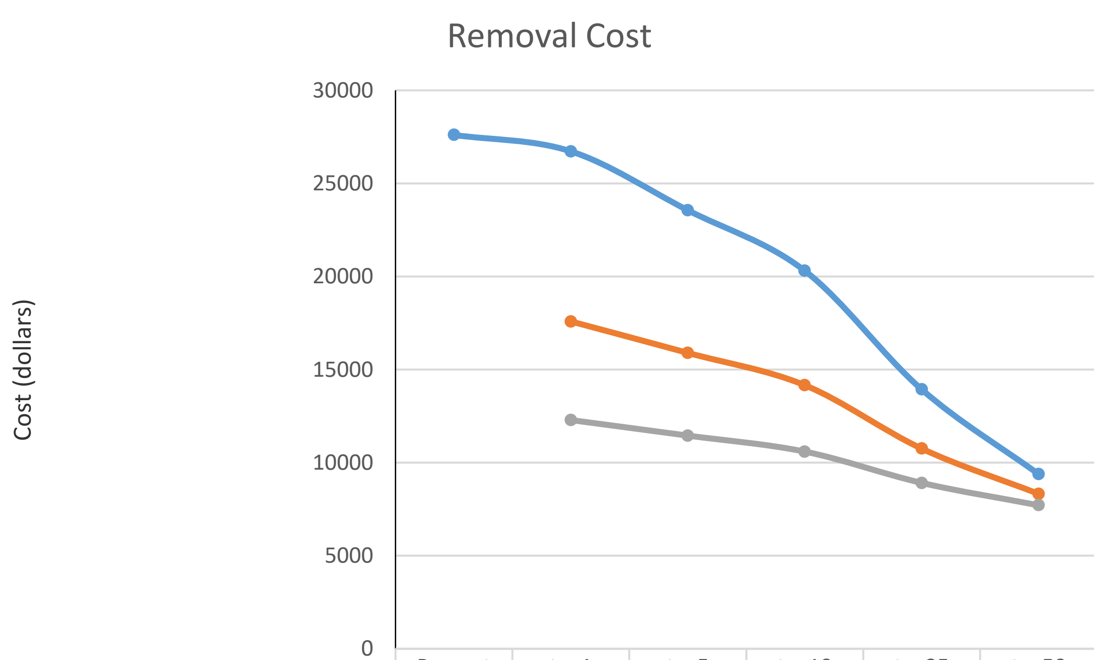


	Present	t = 1	t = 5	t = 10	t = 25	t = 50
O&M total cost at year t	0	306	1405	2532	4745	6324

Chart 1- O&M Program Only Cost (dollars)

Scenario #2: Removal

Chart 2 presents the costs of removal at various time intervals over 50 years for three different situations: removal not occurring during renovation or demolition, removal occurring during renovation, and removal occurring during demolition. The predicted removal costs were calculated by selecting the applicable costs associated with removal, as done in previous research by Dewees (1986). Average costs were adjusted for inflation and multiplied by the square footage of the building. Removal costs that occurred during any year past the present were discounted using a discount rate of 4.5%. The O&M program calculated at $320 per year discounted at 4.5% was added to total cost for the year.

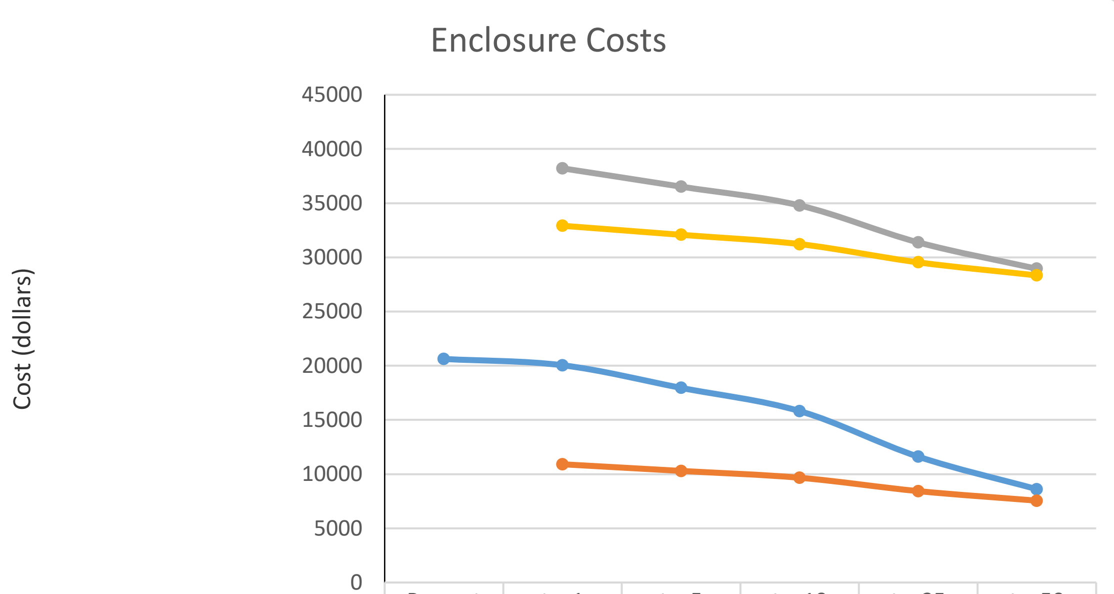


	Present	t = 1	t = 5	t = 10	t = 25	t = 50
Removal at year t	27605	26722	23557	20308	13930	9380
Removal at rennovation in year t		17586	15896	14160	10753	8323
Removal at demolition in year t		12287	11452	10594	8911	7710

Chart 2- Removal Cost (dollars)

Scenario #3: Enclosure

Chart 3 presents the costs of enclosure at various time intervals over 50 years for four different situations: enclosure not occurring during renovation or demolition, enclosure occurring during renovation, enclosure occurring at present with removal occurring later during renovation, and enclosure occurring at present with removal occurring later during demolition. The predicted enclosure costs were calculated by selecting the applicable costs associated with enclosure, as done in previous research by Dewees (1986). Average costs were adjusted for inflation and multiplied by the square footage of the building. Enclosure and/or removal costs that occurred during any year past the present were discounted using a discount rate of 4.5%. The O&M program calculated at $320 per year discounted at 4.5% was added to the total cost for the year.

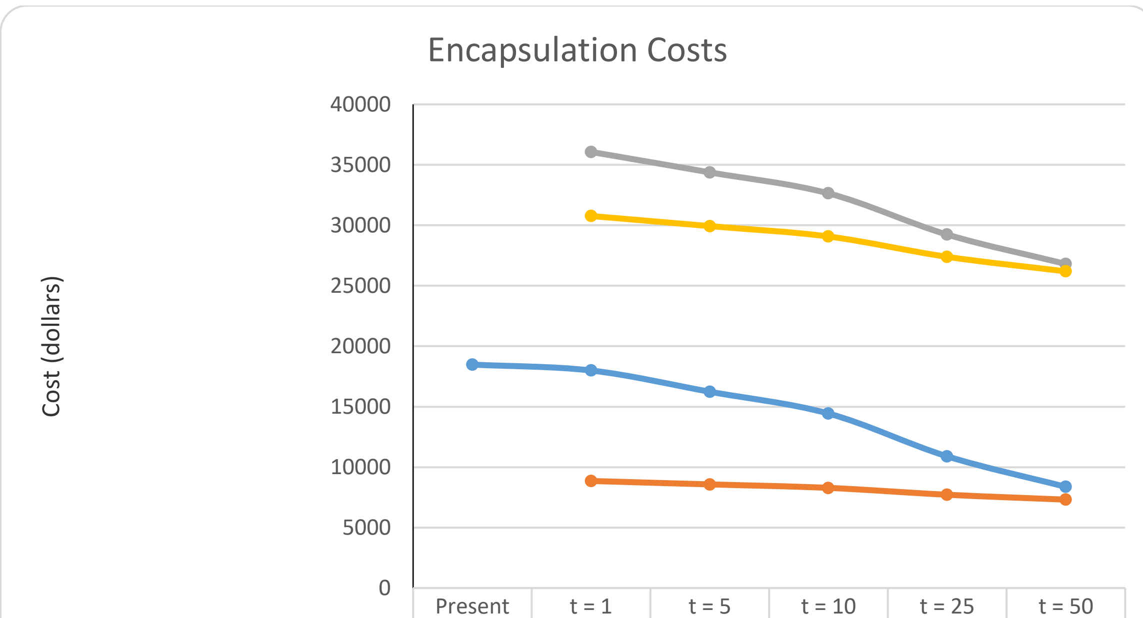


	Present	t = 1	t = 5	t = 10	t = 25	t = 50
Enclose at year t	20625	20043	17956	15813	11608	8607
Enclose at renovation in year t		10907	10295	9665	8431	7550
Enclose now + remove at renovation in year t		38211	36521	34785	31378	28948
Enclose now + remove at demolition in year t		32912	32077	31219	29536	28335

Chart 3- Enclosure Cost (dollars)

Scenario #4: Encapsulation

Chart 4 presents the costs of encapsulation at various intervals over 50 years for four different situations: encapsulation not occurring during renovation, encapsulation occurring during renovation, encapsulation occurring at present with removal occurring later during renovation, and encapsulation occurring at present with removal occurring later during demolition. The calculations used to predict encapsulation costs were calculated by selecting the applicable costs associated with encapsulation, as done in previous research by Dewees (1986). Average costs were adjusted for inflation and multiplied by the square footage of the building. Encapsulation and/or removal costs that occurred during any year past the present were discounted using a discount rate of 4.5%. The O&M program calculated at $320 per year discounted at 4.5% was added to the total cost for the year.

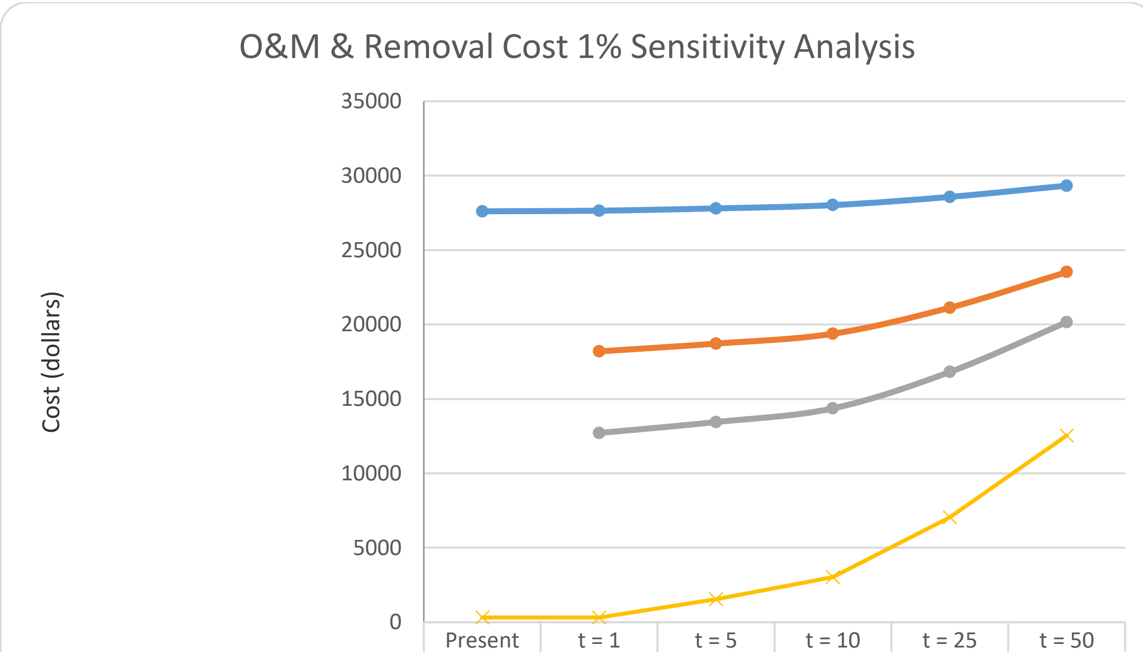


	Present	t = 1	t = 5	t = 10	t = 25	t = 50
Encapsulate at Year t	18480	17990	16234	14432	10894	8370
Encapsulate at Renovation in Year t		8854	8573	8284	7717	7313
Encapsulate Now + Remove at Renovation in Year t		36066	34376	32640	29233	26803
Encapsulate Now + Remove at Demolition in Year t		30767	29932	29074	27391	26190

Chart 4- Encapsulation Cost (dollars)

Sensitivity Analysis

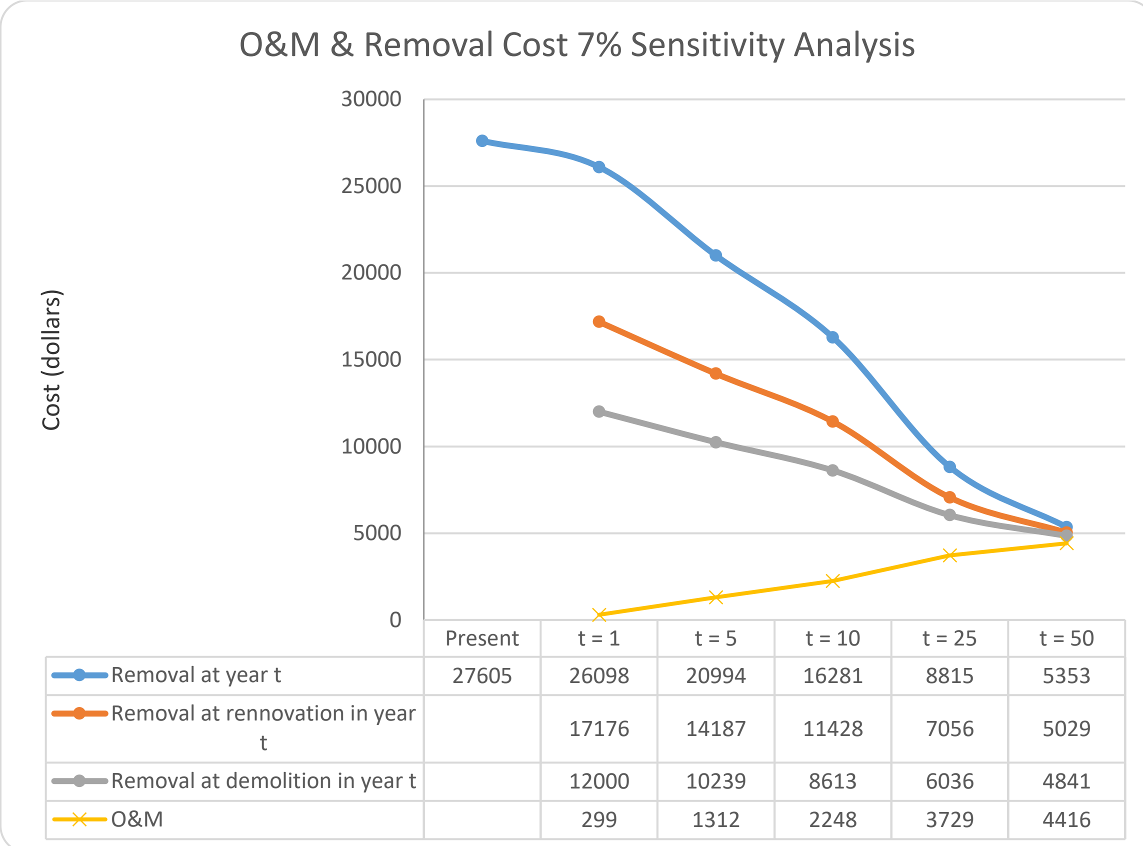
Chart 5 displays the results of the sensitivity analysis performed at a 1% discount rate.



	Present	t = 1	t = 5	t = 10	t = 25	t = 50
Removal at year t	27605	27648	27799	28021	28573	29327
Removal at rennovation in year t		18195	18716	19379	21128	23522
Removal at demolition in year t		12712	13446	14365	16810	20155
O&M	320	316	1534	3031	7047	12542

Chart 5- O&M & Removal Cost 1% Sensitivity Analysis

Chart 6 displays the results of the sensitivity analysis performed at a 7% discount rate.



	Present	t = 1	t = 5	t = 10	t = 25	t = 50
Removal at year t	27605	26098	20994	16281	8815	5353
Removal at rennovation in year t		17176	14187	11428	7056	5029
Removal at demolition in year t		12000	10239	8613	6036	4841
O&M		299	1312	2248	3729	4416

Chart 6- O&M & Removal Cost 1% Sensitivity Analysis

Discussion

The four scenarios presented in this study illustrate the least-cost approach for asbestos abatement for a 1,000 square foot building. It was hypothesized that the least-cost approach for asbestos abatement decisions would be to defer abatement to renovation or demolition. To test this hypothesis, costs were estimated using previous research and adjusted for inflation. There were many limitations to this study, such as the timeframe that was allotted to conduct research for this project, as well as financial constraints to conduct more research and interviews with experts in the field. Additionally, the variance in costs as they pertained to condition of the building, location/type of asbestos material, labor wages, moving costs, alternative space costs, productivity costs, etc. were also limitations.

Scenario #1 illustrated the associated cost for an O&M program for building managers when ACM was found to be in good condition. For this scenario, it was assumed that ACM was not disturbed and could remain in place indefinitely. Compared to the three other scenarios, this scenario was found to be the least-cost approach. However, if non-disturbance and indefiniteness assumptions do not hold, the least-cost solution is given by scenario 2, 3 or 4. Results indicated that even after 50 years of implementing an O&M program, the discounted cost of $6,324 was less than removal at present time.

Scenario #2 illustrated the associated costs for removal, with the highest cost difference occurring when removal was completed at demolition. The cost to remove ACM at the present time was found to be $27,605 compared to $12,287 for removal at demolition only one year later. This is over a 50% reduction in cost. The cost difference could be attributed to having no employee disturbance and no replacement material costs. For time intervals up to 10 years, removal at demolition was around half the cost of removal at present time. After 10 years the difference in cost declines significantly. Removal at renovation was found to be the next best choice. Compared to removal now, removal at renovation in one year reduced costs by approximately 36%. If removal could be deferred until renovation in 50 years, costs were shown to be reduced almost 70% when compared to removal at present time. It is worthy to note that at 50 years the one time discounted cost for removal was relatively small, and a majority of the cost for all removal options was due to the cost of the O&M program over the years.

Scenario #3 illustrated the costs for enclosure. It is important to note that enclosure is a temporary option because according to NESHAP, ACM must be removed prior to building renovation or demolition. Results indicated that enclosure involved the same costs as removal, except enclosure was less expensive per square foot to complete. Based on this finding, enclosure alone was approximately 25% cheaper than removal. If enclosure could be deferred until renovation in one year, enclosure costs were shown to be reduced by 50%. Considering the long-term costs, when the enclosed material was to eventually be removed, the costs rose significantly. This increase was due to the material needing to be enclosed at the present time and the cost of O&M being added per year until removal, in addition to the removal cost that occurred at renovation or demolition. For this scenario, the enclosure with removal at renovation cost was approximately 29-46% higher overall years than removing it at the present. Slight cost savings were shown to be achieved from enclosure at present with removal occurring during demolition, but the cost was still higher than removal at present time.

Scenario #4 illustrated the costs for encapsulation. Similar to enclosure, it is important to note that enclosure is only a temporary option because according to NESHAP, ACM must be removed prior to building renovation or demolition. Research has shown that encapsulation is the least expensive abatement option per square foot, other than implementing an O&M program. Compared to removal, encapsulation was approximately 33% cheaper. If encapsulation could be completed at renovation, then encapsulation costs could be reduced by over 50% compared to encapsulating at present. Considering the long-term costs, when the encapsulated material was removed during renovation or demolition, total cost rose significantly. This increase was due to encapsulating a material at present time and then later removing it during renovation, thus adding both costs together. This results in a cost increase of around 20% when renovation occurred in the short-term compared to removal at present. If encapsulated ACM removal occurred during renovation in 25 to 50 years, results indicated that the present value cost became very close to the cost of removal at present time. Slight savings can be found when encapsulating and removing at demolition versus renovation. In the short-term, encapsulation and removal at demolition results in a higher cost than removal at present. In the long-term, the cost is similar to removal at present.

The previous results of the study were calculated at a 4.5% discount rate. A sensitivity analysis was performed at a 1% and 7% discount rate. The 7% discount rate resulted in the same decision making criterion as the 4.5% discount rate. As can be seen in Chart 6, an O&M program was the least-cost approach, while deferring removal for all scenarios also reduced cost. The sensitivity analysis performed at 1% discount rate resulted in different findings. With such a low discount rate, the cost of the O&M program throughout the years raised the present value of future removal scenarios. As can be seen in Chart 5, for all removal scenarios, deferring removal resulted in a higher cost due to the cost of the O&M program. The amount did not increase drastically, but costs were higher than the previous years.

These results provide valuable insights to business owners that need to identify least-cost asbestos abatement options. At a 4.5% discount rate, results indicated that if asbestos was non-disturbed and could remain in place indefinitely, the least-cost approach for asbestos abatement at various intervals over 50 years was an O&M program. If not feasible, results indicated that the next least-cost approach was to defer abatement to renovation or demolition, thus supporting the original hypothesis. Dewees (1986) found that the costs associated with abatement were lessened when abatement was performed with planned building renovation or demolition, as costs such as moving costs, alternative space, and loss of productivity did not directly result from the abatement option but rather the planned renovation or demolition. Furthermore, with demolition, replacement materials were not necessary. This was found to be true in the current study as well. Additionally, results indicated that the highest-cost option for business owners occurred when asbestos was enclosed or encapsulated at the present time and then removed at a later time, due to the total cost of both. This finding was supported by the EPA (1985), which found that costs associated with enclosure and encapsulation were less expensive in the short-term, but were found to be more expensive in the long-term due to the total cost of both. It is important to note that at a 1% discount rate the hypothesis was not supported for deferring abatement. These results demonstrated the importance for business owners to evaluate costs at the appropriate discount rate over many years, for all applicable scenarios before selecting an abatement option.

Conclusion

ACM is a human health risk when it is friable and disturbed, or when it is likely to be disturbed. The current study provided insights about the least-cost approach to asbestos abatement for an office building under four different scenarios. Costs were estimated using information from previous research on industry related costs, and were then adjusted using a discount rate of 4.5%. It was found that implementing an O&M program was the least-cost approach. However, due to the nature and condition of the ACM, that approach was not always feasible. In situations where ACM was in poor condition, there were no cost considerations to be made due to the health concern. Therefore, removal was necessary as soon as possible. In situations where the ACM was in good condition but was likely to be disturbed, removal at renovation or demolition was shown to be the least-cost approach. Results also indicated that long-term costs should be considered, because enclosure or encapsulation at present time followed by removal at later time proved to be the highest-cost approach. The choice of low discount rate proved to have significant implications on the decision to defer abatement. If a low discount rate is chosen, building owners may find it least-cost to perform abatement at the present time.

Limitations and Future Research

This study evaluated a sample building with a certain type and amount of ACM. Costs were defined for the O&M program, abatement options, and associated costs from dislocating workers. In reality, every building is different, different ACM in different quantities and conditions. It is possible business owners will find different costs for abatement depending on their county, city, or state. Additionally, business owners will face different costs associated with dislocating workers. Some business may have room to move employees to another part of the building, in which case moving, lost productivity, and alternative space costs may not be a factor. This study provided a general approach that business owners can utilize when making abatement decisions. Business owners must choose their discount rate, calculate what an O&M program costs per year, receive abatement quotes, and calculate their costs due to worker dislocation, which will allow them to follow the decision-making criteria outlined in this study to find their own least-cost approach. As there were many limitations to the current study, further research should be done to determine if there are more up-to-date estimates as they pertain to any and all costs associated with the various scenarios.

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Appendix A

Surfacing Materials Decision Table

Potential for Future Damage, Disturbance, or Erosion		**Current condition of ACM**	
	Good	**Minor Damage or Deterioration**	**Poor**
Low	No further action now beyond Special O&M Program	Selective or complete removal as soon as possible	Removal as soon as possible
High	Removal, enclosure, encapsulation, Integrated with other building activities	Selective or complete removal as soon as possible	Removal as soon as possible

Source: EPA (1985)

Appendix B

Thermal System Insulation Decision Table

Potential for Future Damage, Disturbance, or Erosion		**Current condition of ACM**	
	Good	**Minor Damage or Deterioration**	**Poor**
Low	No further action beyond Special O&M Program	Patching or a new jacket as soon as possible	Removal and replacement as soon as possible
High	Removal, integrated with other building activities	Patching or a new jacket as soon as possible. Removal, integrated with other building activities	Removal and replacement as soon as possible

Source: EPA (1985)

Appendix C

Costs Associated with Asbestos Control (1985 dollars)

Type of work	Cost per square foot
Removal, disposal, and install of substitute	$4.25 - 9.14
Removal and disposal alone	$3.31 - 7.71
Enclosure	$3.50 - 3.75
Encapsulation	$1.85 - 3.51
Moving	$0.50 - 1.00
Alternative space for two months	$1.67 - 3.33
Removal, re-installation, cost of dislocating tenants	$8.92 - 15.97
Removal deferred until renovation	$5.08 - 10.81
Removal at demolition	$3.31 – 7.71

Source: Dewees (1986)