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April 2010

DEFENSE INFRASTRUCTURE

DOD Needs to Determine and Use the Most Economical Building Materials and Methods When Acquiring New Permanent Facilities

GAO-10-436

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DOD Needs to Determine and Use the Most Economical Building Materials and Methods When Acquiring New Permanent Facilities

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Highlights

Highlights of GAO-10-436, a report to the Subcommittee on Readiness, Committee on Armed Services, House of Representatives

Why GAO Did This Study

To meet the challenges associated with a threefold increase in the Army's military construction program between fiscal years 2005 and 2009, the Army adopted numerous changes, including the expanded use of wood materials and modular building methods, designed to reduce building costs and timelines for new facilities. With the changes, the Army set goals to reduce building costs by 15 percent and timelines by 30 percent. The Army, Navy, and Air Force have also faced challenges associated with incorporating both antiterrorism construction standards and sustainable design ("green") goals into new facilities. GAO was asked to (1) assess the Army's progress in meeting its goals, (2) evaluate the merits from the Army's expanded use of wood materials and modular building methods, and (3) examine potential conflicts between antiterrorism construction standards and sustainable design goals. GAO reviewed relevant documentation, interviewed cognizant service officials, analyzed selected construction project data, and visited five Army installations to review facilities built with alternative materials and methods.

What GAO Recommends

GAO recommends that the Department of Defense (DOD) determine the merits and long-term costs from the use of alternative building materials and methods and subsequently revise its military construction guidance, as deemed appropriate. DOD generally agreed with the recommendations.

View GAO-10-436 or key components.
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What GAO Found

The Army set goals to reduce its estimated construction costs by 15 percent and building timelines by 30 percent, but it did not monitor goal achievement and thus did not know to what extent the goals had been met or whether changes made to its military construction program resulted in actual reductions in facility costs. GAO's review of selected project information showed that the Army did reduce the estimated cost of some facility construction projects and shortened building timelines during fiscal years 2007 through 2009, but it did not meet its overall stated goals. For example, GAO found that the average building timeline for one key measurement (design start to ready for occupancy) was reduced by about 11 percent—an improvement, but less than the 30 percent goal. The Army discontinued the numerical goals in fiscal year 2010, and Army officials stated that, although the specific goals might not have been achieved, they believed that the Army's efforts were successful in dampening the escalation of Army facilities' costs and would continue to help ensure cost-effective and timely facilities in future years.

The Army appears to have achieved some savings in selected construction projects by expanding the use of wood materials and modular construction methods for some of its facilities, but GAO found little quantitative data on whether the use of these materials and methods will result in savings over the long term compared to the traditional use of steel, concrete, and masonry materials and on-site building methods. Without long-term or life-cycle analyses that consider not only initial construction costs but also possible differences in facility service lives and annual operating and maintenance costs between the construction alternatives, it is not clear that the Army's expanded use of wood materials and modular building methods will achieve the Army's intended purpose of reduced facility costs over the long term. The Navy and the Air Force generally disagreed with the Army's view and believed that the use of wood materials and modular construction will result in facilities with shorter service lives and higher life-cycle costs. However, none of the services had the analyses to support its views. Without additional study and analysis, DOD will not know whether military construction program guidance needs to be changed to ensure that facilities are constructed with materials and methods that meet needs at the lowest cost over the long term.

Conflicts between antiterrorism building standards and sustainable design goals exist, but military service officials stated that the conflicts are considered to be manageable. GAO's review of 90 Army, Navy, and Air Force military construction projects, approved during fiscal years 2007 through 2009, showed that although incorporating the standards and the goals in new facilities added to construction costs, 80 of the projects required no special steps or workarounds to meet both the standards and the goals. However, service officials noted that achieving higher levels of sustainability in future construction projects while still meeting the antiterrorism standards would further increase initial facility costs and create additional design challenges.

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DOD	Department of Defense

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United States Government Accountability Office
Washington, DC 20548

April 30, 2010

The Honorable Solomon Ortiz
Chairman
The Honorable J. Randy Forbes
Ranking Member
Subcommittee on Readiness
Committee on Armed Services
House of Representatives

The Army has been faced with a significant challenge to meet the facility needs associated with several recent initiatives, such as the transformation of the Army's force structure, the permanent relocation of thousands of overseas military personnel back to the United States, the implementation of Base Realignment and Closure actions, and the planned increase in the Army's active-duty end strength. Taken together, the Army estimated that these initiatives would result in a threefold increase in the Army's military construction program with appropriated funding increasing from about $3.4 billion in fiscal year 2005 to a peak of about $10.7 billion in fiscal year 2009 before beginning to decrease back to more historical levels.

The Army concluded that if it continued to use traditional military construction acquisition and building practices then it could not successfully meet the challenges associated with such a large increase in the volume and costs of facility construction, as well as the need to complete new required facilities in time to meet planned movements of organizations and personnel. Thus, in 2006, the Army adopted a strategy, known as military construction transformation, which included numerous changes to its traditional practices that were designed to reduce facility acquisition costs and construction timelines. Among the changes were the development of standard designs for common facility types, the use of a standardized format to obtain contractor bids for facility construction projects, a transition from "design-bid-build" to "design-build" project delivery,[1] and a change from including detailed, prescriptive construction

[1]Design-bid-build is a project delivery method where a project's design is contracted out and, after the design is completed, the project's construction is solicited and normally awarded to a separate entity. Design-build is a delivery method where the design and construction are contracted out to a single entity. By using one contractor and overlapping a project's design and construction phases, this approach attempts to reduce project risk and construction timelines.

requirements in facility solicitations to the use of performance-based criteria that focused on what the Army needed rather than on how to meet the needs. Another change in the Army's strategy was the expanded use of all types of construction materials and methods allowed by Department of Defense (DOD) building guidance. This included greater use of wood materials and modular building methods, as compared to the use of steel, concrete, and masonry materials and on-site building methods traditionally used by the Army, Navy, and Air Force for larger permanent facilities, such as administrative buildings and barracks.

In view of the expected results from the implementation of its new military construction transformation strategy, the Army established goals to reduce its military construction costs by 15 percent and facility construction timelines by 30 percent beginning in fiscal year 2007. The Army planned to implement the cost reduction goal by having project planners reduce the estimated cost of planned facilities by 15 percent and then request funding from the Congress for the reduced amount. Thus, the cost goal was not directly related to actual facility costs but rather to estimated facility costs. While continuing to apply the strategy to its military construction program, the Army discontinued these numerical goals in fiscal year 2010, stating that most cost and timeline reduction benefits from the strategy had been obtained by the end of fiscal year 2009.

In addition to facing challenges from the significant growth in its military construction program, the Army, as well as the Navy and the Air Force, has also faced challenges associated with incorporating both antiterrorism construction standards and sustainable design goals into new facilities.[2] As required by Section 2859 of Title 10, DOD has developed and implemented antiterrorism construction standards designed to reduce facility vulnerability to terrorist attack and improve the security of facility occupants.[3] The standards include 22 mandatory standards, such as requiring open areas around new facilities to keep explosives at a distance from the facilities, and 17 recommended but optional measures, such as avoiding exterior hallway configurations for inhabited facilities. For decades, the federal government has attempted to improve energy

[2]Sustainable design goals, sometimes referred to as "green" building goals, include facility design and construction goals to avoid resource depletion of energy, water, and raw materials; prevent environmental degradation caused by facilities and infrastructure; and create and build environments that are livable, comfortable, safe, and productive.

[3]10 U.S.C. § 2859(a)(2).

efficiency and energy and water conservation at federal facilities and, in January 2006, DOD joined 16 other federal agencies in signing a memorandum of understanding that committed the agency to leadership in designing, constructing, and operating high-performance and sustainable buildings.[4] Challenges from incorporating the antiterrorism standards and sustainable goals into new facilities include not only increased costs, but also dealing with potential conflicts between the standards and the goals, such as providing required open areas around new facilities, which reduces development density, while recognizing sustainable design goals related to increasing development density.

You asked us to assess the Army's progress in meeting its military construction cost and timeline reduction goals, evaluate the Army's expanded use of nontraditional construction materials and methods, and review potential conflicts and costs from incorporating antiterrorism standards and sustainable design goals in new military facilities. Thus, this report (1) assesses the Army's measurement and achievement of its military construction cost and timeline reduction goals, (2) evaluates the merits and economic impacts from the Army's expanded use of wood materials and modular building methods for permanent facilities, and (3) discusses potential conflicts between antiterrorism construction standards and sustainable design goals and the costs to incorporate the standards and goals in new facilities.

To address these objectives, we reviewed applicable documentation on how the Army implemented and monitored its 15 percent construction cost and 30 percent building time frame reduction goals and interviewed Army officials and analyzed Army data for a non-probability sample of 75 Army projects approved in fiscal years 2007 through 2009 to determine whether the projects met the cost reduction goal. The projects selected represented a range of facility types and geographic locations and were in the categories of facilities subject to the cost goal. We also determined whether the Army met its building timeline reduction goal by comparing actual building timelines for all completed projects before and after the goals were established. In addition, we interviewed Army, Navy, and Air Force officials and reviewed documentation, policies, and construction guidance on the Army's expanded use of wood materials and modular building methods; obtained information about how different building

[4]See Memorandum Of Understanding, *Federal Leadership in High Performance and Sustainable Buildings* (Jan. 24, 2006).

materials and methods affect initial construction costs, long-term costs, and durability of new military facilities; summarized studies from construction industry groups on how different building materials affect construction costs; visited five Army installations to review recent construction projects and discuss with local officials the use of wood materials and modular building methods; and met with developers of two military privatized, unaccompanied personnel housing projects to discuss the building materials and methods used in those projects. Further, we reviewed applicable DOD policies, guidance, and goals related to incorporating antiterrorism construction standards and sustainable design goals in new military facilities; interviewed military service officials about how antiterrorism standards and sustainable design goals affect construction costs and how potential conflicts between the standards and goals are addressed; and followed up with project planners on a non-probability sample of 90 Army, Navy, and Air Force military construction projects from fiscal years 2007 through 2009 to obtain details on any conflicts encountered when incorporating the standards and goals in the projects. We selected projects from a list of all Army, Navy, and Air Force military construction projects approved during fiscal years 2007 through 2009 to represent a range of facility types and geographic locations and included 10 Army, 10 Navy, and 10 Air Force projects approved in each of the 3 years. Although we did not independently validate construction cost and building timeline data provided by the military services, we discussed with the officials steps they have taken to ensure reasonable accuracy of the data. As such, we determined the data to be sufficiently reliable for the purposes of this report.

We conducted this performance audit from March 2009 to February 2010 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives. Further details on our scope and methodology can be found in appendix I.

Results in Brief

The Army set goals to reduce its estimated construction costs by 15 percent and building timelines by 30 percent, but it did not monitor goal achievement and therefore did not know to what extent the goals were met or whether changes adopted under its military construction transformation strategy resulted in actual reductions in facility costs. However, our review of selected project information showed that the

Army did reduce the estimated cost of some facility construction projects and shortened building timelines during fiscal years 2007 through 2009, but it did not meet its overall stated goals. Effective management practices call for not only setting program goals but also for monitoring goal achievement so that results can be measured and adjustments can be made to programs, if needed, to better achieve goals. Yet, the Army did not establish a framework to measure changes in facility construction costs and building timelines when it established goals to reduce costs and timelines beginning in fiscal year 2007, and as a result, the Army was not in a position to make adjustments in its application of these goals. Furthermore, we found that the Army did not subject all Army facility projects to the 15 percent cost reduction goal during fiscal years 2007 through 2009. To illustrate, the Army decided to only subject projects funded by the base realignment and closure program to the goal in fiscal year 2007 and, in fiscal year 2009, the Army decided to only apply the goal reduction to five types of facilities—brigade, battalion, and company headquarters buildings, barracks, and dining facilities. To obtain some insight into the Army's attainment of its cost goal, we reviewed the estimated cost of 75 facility projects in the categories that were subject to the goal and found that the goal was met in 31 (41 percent) of the facilities, but not met in 44 (59 percent) of the facilities.[5] However, some reduction, but less than 15 percent, was made in the estimated cost of 24 of the 44 facilities that did not meet the goal. To obtain some insight into the Army's attainment of its 30 percent building timeline reduction goal, we compared actual Army building timelines for all projects before and after the goal was established. We found that the average building timeline for one key Army timeline measurement (design start to ready for occupancy) was reduced by about 11 percent—an improvement, but less than the Army's 30 percent goal. The Army discontinued these numerical goals in fiscal year 2010, and Army officials stated that, although the specific goals might not have been achieved, they believed that the Army's efforts to transform its military construction acquisition and building practices were successful in dampening the escalation of Army facilities' costs and would continue to help ensure cost-effective and timely facilities in future years.

[5]The Army implemented the cost reduction goal by having project planners reduce the estimated cost of planned facilities by 15 percent, requesting funding from the Congress for the reduced amount, and then attempting to award and complete the project within the approved funding amount. Although the Army had information on the actual costs of completed military construction projects, the Army did not routinely document the actual costs of the individual facilities included in the projects. For this reason, we could not determine whether any facilities subject to the Army's cost reduction goal resulted in actual savings compared to cost estimates based on DOD cost estimating guidance.

Although the Army appears to have achieved some savings in initial construction costs by expanding the use of wood materials and modular construction methods for some permanent facilities, we found little quantitative information on whether the use of these materials and methods will result in savings over the long term compared to the traditional use of steel, concrete, and masonry materials and on-site building methods. Without long-term or life-cycle analyses that consider not only initial construction costs but also possible differences in facility service lives and annual operating and maintenance costs between the construction alternatives, it is not clear that the Army's expanded use of wood materials and modular building methods will achieve the Army's intended purpose of reduced facility costs over the long term. Navy and Air Force officials generally disagreed with the Army's view saying that the use of wood materials and modular construction—as compared to the use of steel, concrete, and masonry materials and on-site construction methods—would result in facilities with shorter service lives and higher, not lower, life-cycle costs. However, none of the services had substantial quantitative information or analyses to support its views. Also, during visits to private organizations that represented the interests of wood, modular building, and concrete and masonry industries, we found various views and opinions on the long-term merits and economic benefits from the use of alternative construction materials and building methods, but did not find documented analyses comparing the actual life-cycle costs of facilities constructed with alternative materials and methods. We did find that the Army apparently achieved initial construction cost savings by using wood-frame construction in several barracks projects that were initially designed to be built with steel, concrete, and masonry. For example, Army officials noted that a fiscal year 2006 Fort Carson, Colorado, barracks project was estimated to cost about $35 million based on actual contract bids and the use of steel, concrete, and masonry construction materials. However, after switching the design to wood-frame construction, the project was subsequently awarded for about $24 million, a savings of about $11 million (31 percent) in estimated costs. Nonetheless, unless the services perform additional study and analysis to determine the relative merits and long-term economic impacts from the use of alternative construction materials and methods, DOD will not know whether the use of wood materials and modular building methods results in the most economical long-term building approach or whether DOD's military construction program guidance needs to be changed to ensure that new facilities are constructed with materials and methods that meet requirements at the lowest cost over the long term. Thus, we are recommending that DOD determine the merits and long-term costs from the use of alternative construction materials and methods for new

common facilities where alternative materials may be appropriate, such as administrative buildings and barracks, and subsequently revise its military construction guidance, as deemed appropriate.

Although areas of conflict exist when designing facilities that meet both antiterrorism construction standards and sustainable design goals, military service officials stated that the conflicts are manageable and facilities are routinely designed and built that meet both the standards and the goals. For example, the antiterrorism mandatory building standard to provide standoff distances around new facilities reduces development density and thus conflicts with a sustainable design goal to increase development density. Similarly, a sustainable design goal related to greater use of windows to increase natural lighting conflicts with the recommended antiterrorism building measure related to minimizing hazards from flying glass fragments from windows. To help deal with such conflicts, DOD uses a facility planning tool that identifies and addresses the potential conflicts from integrating required antiterrorism standards with sustainable design goals. Military service officials stated that with use of the tool and a comprehensive design approach, they were able to develop successful building solutions that ensured both secure and high-performance facilities. The officials also noted that their goal was to design and construct all new major military construction facilities to meet sustainable standards established by the U.S. Green Building Council's Leadership in Energy and Environmental Design Green Building Rating System, while still meeting the mandatory antiterrorism building standards.[6] To assess how the services were dealing with the conflicts, we followed up with the project planners responsible for 90 military construction projects from a non-probability sample of Army, Navy, and Air Force projects approved during fiscal years 2007 through 2009. According to the planners, 80 (89 percent) of the 90 projects required no special steps or workarounds to meet both antiterrorism standards and sustainable design goals. For the projects where special steps or workarounds were needed, most issues related to required building standoff distances and facility windows. The planners also reported that, primarily because of the required standoff

[6]The U.S. Green Building Council's Leadership in Energy and Environmental Design Green Building Rating System defines sustainable features for buildings and includes a set of performance standards which can be used to certify the design and construction of buildings. By meeting the standards during facility design and construction, builders can earn credits and become certified in accordance with an established four-level scale—certified, silver, gold, and platinum. The military services' goal in fiscal year 2009 was for all new major military construction buildings to be silver-level certifiable, which is the second level on the four-level scale.

distances, 18 (20 percent) of the 90 projects resulted in additional land use, community decentralization, or installation development sprawl.[7] For example, planners of a fiscal year 2008 instruction building at Fort Huachuca, Arizona, reported that, because of the antiterrorism standoff distance standards, the building site was approximately 50 percent larger than required if there were no standoff requirements. According to service officials, as well as our review of cost estimates from the 90 sample projects, incorporating antiterrorism standards in new facilities typically adds about 1 to 5 percent to construction costs and incorporating sustainable design building features typically adds about 2 percent to construction costs. Service officials noted that achieving higher levels of sustainability while still meeting the antiterrorism standards would increase initial facility costs and create additional design challenges.

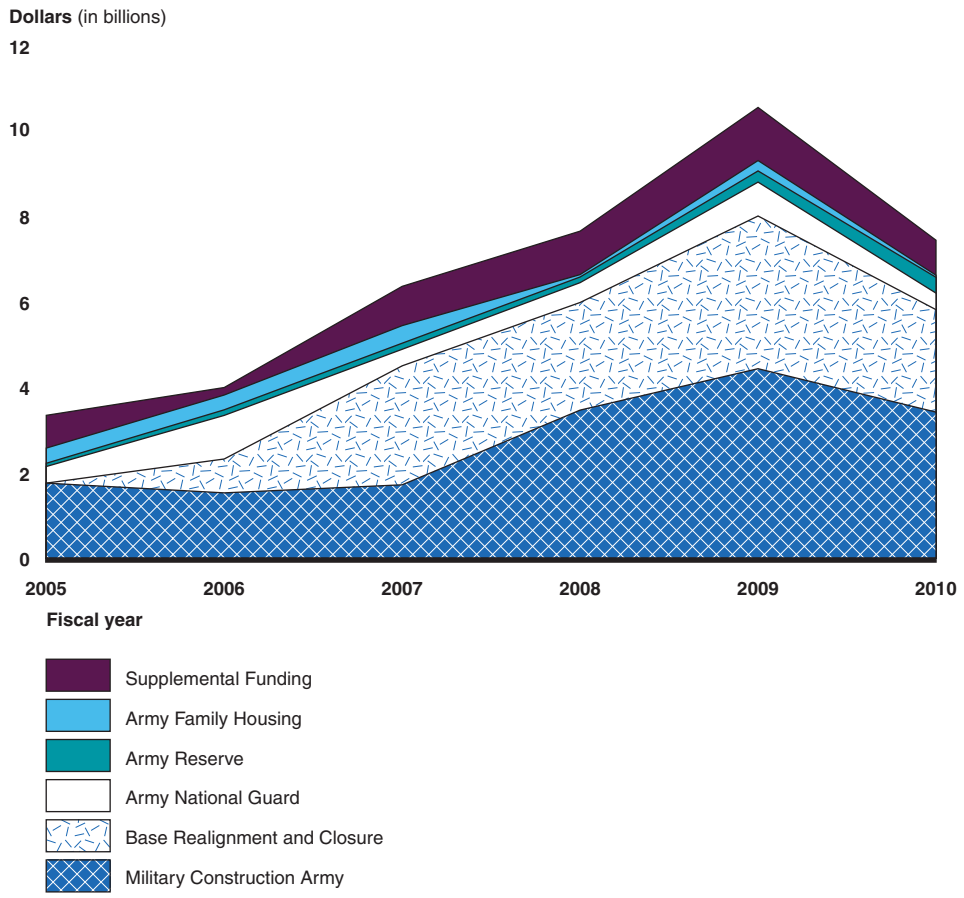
In oral comments on a draft of this report, DOD generally agreed with our recommendations and stated that it had already begun steps to implement them. We discuss DOD's comments in detail later in this report.

Background

The Army has been faced with a significant challenge to meet the facility needs associated with several recent initiatives, such as the transformation of the Army's force structure, the permanent relocation of thousands of overseas military personnel back to the United States, the implementation of Base Realignment and Closure actions, and the planned increase in the Army's active-duty end strength. As shown in figure 1, the Army estimated that taken together these initiatives resulted in a threefold increase in the Army's military construction program with appropriated funds increasing from about $3.4 billion in fiscal year 2005 to a peak of about $10.7 billion in fiscal year 2009 before beginning to decline in fiscal year 2010.

[7]In its June 18, 2009 report on the National Defense Authorization Act for Fiscal Year 2010 (H.R. Rep. No. 111-166), the House Armed Services Committee expressed concern about low-density development at military installations caused by compliance with antiterrorism construction requirements. The committee directed the Secretary of Defense to submit to the congressional defense committees a report that reviews current antiterrorism/force-protection measures and possible alternative measures, considering community-based sustainable design techniques.

Figure 1: Army Military Construction Program by Type of Funding between Fiscal Years 2005 and 2010



Source: GAO analysis of appropriated funding data provided by the Army.

Note: Figure does not include $264 million of American Reinvestment and Recovery Act funds appropriated for Army and Army National Guard military construction and Army family housing construction in fiscal year 2009.

The Army Adopted Changes to Its Military Facility Acquisition and Construction Practices

To meet the challenges associated with the large increase in its military construction program and ensure that required new facilities would be completed in time to meet planned movements of organizations and personnel, the Army concluded that it could not continue to rely on its traditional military facility acquisition and construction practices. The Army's solution was the adoption of a new strategy in 2006 that the Army termed military construction transformation. The strategy included numerous changes to the Army's traditional practices that were designed

to reduce facility acquisition costs and construction timelines. Included among the changes were the following:

- The development of clear requirements that need to be met in 43 different types of Army facilities and the creation of standard designs for 24 common facility types, such as headquarters buildings, company operations and tactical equipment maintenance facilities, barracks, dining facilities, and child care centers.

- A transition from "design-bid-build" project delivery, where a project's design and construction are normally awarded via separate contracts, to "design-build" project delivery, where a project's design and construction are awarded to a single contractor. By using one contractor and overlapping the design and construction phases, the design-build approach attempts to reduce project risk and construction timelines.

- The development of a standard solicitation approach for most common-type facilities that used performance-based criteria focused on what the Army needed rather than on detailed, prescriptive criteria that focused on how the Army's requirements should be met. Under the approach, the Army revealed to potential bidders the available funding for the project and tasked project bidders to provide an innovative proposal that meets the performance-based criteria while maximizing quality, sustainability, and energy conservation.

Army officials stated that its new standard solicitation approach encouraged potential bidders to develop design solutions that considered the use of all types of construction materials and methods allowed by DOD building guidance. This included the use of wood materials and modular building methods in addition to the use of steel, concrete, and masonry materials and on-site building methods traditionally used by the Army, the Navy, and the Air Force for permanent facilities, such as administrative buildings and barracks. As a result, under its military construction transformation strategy, the Army expanded the use of wood materials and modular building methods for some permanent facilities. Appendix II contains further details on the various categories of construction materials and methods allowed by DOD guidance.

Because the Army believed that the changes it made to its facility acquisition and building practices under its transformation strategy would result in lower construction costs and shorter building timelines, the Army established goals to reduce its military construction costs by 15 percent and facility construction timelines by 30 percent beginning in fiscal year

2007. The Army planned to implement the cost reduction goal by having project planners reduce the estimated cost of planned facilities by 15 percent, requesting funding from the Congress for the reduced amount, and then attempting to award and complete the project within the approved funding amount. Thus, the goal was not directly related to actual facility costs but rather to estimated facility costs. While continuing to apply the strategy to its military construction program, the Army discontinued these numerical goals in fiscal year 2010, stating that most cost and timeline reduction benefits from its strategy would have been obtained by the end of fiscal year 2009.

DOD Antiterrorism Construction Standards and Sustainable Design Goals

As required by Section 2859 of Title 10, DOD has developed and implemented antiterrorism construction standards designed to reduce facility vulnerability to terrorist attack and improve the security of facility occupants.[8] The standards include 22 mandatory standards, such as requiring open areas around new facilities to keep explosives at a distance from the facilities, and 17 recommended but optional measures, such as avoiding exterior hallway configurations for inhabited facilities. Appendix III contains further details on the standards and measures.

For decades, the federal government has attempted to improve energy efficiency and energy and water conservation at federal facilities. Over the past few years, several laws, executive orders, and other agreements added new energy efficiency and energy and water conservation requirements for federal facilities.[9] In particular, in January 2006, DOD joined 16 other federal agencies in signing a memorandum of understanding that committed the agency to leadership in designing,

[8] 10 U.S.C. § 2859(a)(2).

[9] *The* Energy Policy Act of 2005, Pub. L. No. 109-58 (2005), among other things, set energy reduction and efficiency requirements for federal facilities. Executive Order 13423, *"Strengthening Federal Environmental, Energy, and Transportation Management,"* was issued in January 2007 and, among other things, directed that all new building construction and major renovations incorporate sustainable practices and comply with the guiding principles established in the 2006 *Federal Leadership in High Performance and Sustainable Buildings* Memorandum of Understanding. The Energy Independence and Security Act of 2007, Pub. L. No. 110-140, among other things, established new energy and water management requirements and standards for federal buildings and required that sustainable design principles be applied to the siting, design, and construction of federal buildings. Executive Order 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*, was issued in October 2009 and, among other things, directed agencies to establish reduction targets for certain greenhouse gas emissions.

constructing, and operating high-performance and sustainable buildings.[10] The main goals of sustainable design are to avoid resource depletion of energy, water, and raw materials; prevent environmental degradation caused by facilities and infrastructure; and create facilities that are livable, comfortable, safe, and productive.

To help measure the sustainability of new military buildings, DOD uses the U.S. Green Building Council's Leadership in Energy and Environmental Design Green Building Rating System.[11] The system defines sustainable features for buildings and includes a set of performance standards that can be used to certify the design and construction of buildings. The standards are categorized under five major topics—sustainable sites, water efficiency, energy and atmosphere, materials and resources, and indoor environmental quality. By meeting the standards during facility design and construction, builders can earn credits and become certified in accordance with an established four-level scale—certified, silver, gold, and platinum. For fiscal year 2009, DOD set a goal that at least 70 percent of military construction projects would be silver-level certifiable, which is the second level on the four-level scale with platinum being the highest rating. Appendix IV contains additional details on DOD's sustainable design goals.

Responsibilities for DOD's Military Construction Program

The Office of the Deputy Under Secretary of Defense for Installations and Environment has responsibility for DOD's installations and facilities. The office is responsible for establishing policy and guidance for DOD's military construction program and monitoring the execution of the services' military construction projects. The United States Army Corps of Engineers and the Naval Facilities Engineering Command have primary responsibility for planning and executing military construction projects for the Army and the Navy, respectively. Air Force officials stated that the Air Force Center for Engineering and the Environment has primary responsibility for planning and overseeing the construction of Air Force military construction projects, although the Army Corps of Engineers or the Naval Facilities Engineering Command normally executes the

[10]See Memorandum Of Understanding, *Federal Leadership in High Performance and Sustainable Buildings* (Jan. 24, 2006).

[11]See DOD, *Unified Facilities Criteria: Sustainable Development*, UFC 4-030-01 (Dec. 21, 2007).

individual projects for the Air Force and DOD guidance provides these organizations with a role in design and construction.

Prior GAO Reports

Since 1997, we have identified management of DOD support infrastructure as a high-risk area because infrastructure costs have affected the department's ability to devote funds to other more critical programs and needs. In a January 2009 update to our high-risk series, we noted that although DOD has made progress in managing its support infrastructure in recent years, a number of challenges remain in managing its portfolio of facilities and in reducing unneeded infrastructure while providing facilities needed to support several simultaneous force structure initiatives.[12] Further, we noted that because of these issues, DOD's management of support infrastructure remains a high-risk area.

We have issued several reports over the past few years that highlighted aspects of DOD's military construction program and challenges in managing the program. For example, in a 2003 report, we found that opportunities existed to reduce the construction costs of government-owned barracks through greater use of residential construction practices, which included the use of wood materials. However, we also found that questions remained concerning the durability of wood-frame barracks and the ability of wood-frame barracks to meet all antiterrorism force protection requirements.[13] We recommended that engineering studies be undertaken to resolve these questions. DOD concurred with our recommendation and subsequently the Army determined that wood-frame barracks could be built in a manner that met all antiterrorism construction standards. However, DOD did not undertake studies on the durability of wood-frame barracks. In a 2004 report, we found that while DOD had taken a number of steps to enhance the management of the military construction program, opportunities existed for further improvements. Among other things, we recommended that DOD complete management tools for standardizing military construction practices and costs. DOD agreed and subsequently took steps to provide a more consistent approach

[12] GAO, *High-Risk Series: An Update*, GAO-09-271 (Washington, D.C.: Jan. 2009).

[13] GAO, *Military Housing: Opportunities That Should Be Explored to Improve Housing and Reduce Costs for Unmarried Junior Servicemembers*, GAO-03-602 (Washington, D.C.: June 10, 2003).

to managing facilities and planning construction projects and costs.[14] Further, in a September 2007 report, we discussed the complex implementation challenges faced by the Army to meet the infrastructure needs associated with the growth of personnel assigned to many installations as a result of base realignment and closure, overseas force rebasing, and force modularity actions.[15] Also, in October 2009, we issued a report that discussed agencies' progress toward implementing sustainable design and high-performance federal building requirements found in the Energy Independence and Security Act of 2007.[16] This report also addressed the key challenges agencies may encounter when implementing federal building requirements for reducing energy use and managing storm water runoff. Further, in a January 2009 testimony before the House of Representatives' Committee on Transportation and Infrastructure, we noted that investment in infrastructure could reduce energy and operations and maintenance costs and address important energy and water conservation measures as well as other measures outlined within the Energy Independence and Security act of 2007.[17] A list of these reports can be found at the end of this report in the Related GAO Products section.

[14]GAO, *Defense Infrastructure: Long-term Challenges in Managing the Military Construction Program*, GAO-04-288 (Washington, D.C.: Feb. 24, 2004).

[15]GAO, *Defense Infrastructure: Challenges Increase Risks for Providing Timely Infrastructure Support for Army Installations Expecting Substantial Personnel Growth*, GAO-07-1007 (Washington, D.C.: Sept. 13, 2007).

[16]GAO, *Federal Energy Management: Agencies are Taking Steps to Meet High-Performance Federal Building Requirements, but Face Challenges and Need to Clarify Roles and Responsibilities*, GAO-10-22 (Washington D.C.: Oct. 30, 2009).

[17]GAO, *Real Property: Infrastructure Investment Presents Opportunities to Address Long-standing Real Property Backlogs and Reduce Energy Consumption*, GAO-09-324T (Washington, D.C.: Jan. 22, 2009).

The Army Did Not Measure the Achievement of Goals to Reduce Military Construction Costs and Timelines

Because the Army did not measure the achievement of its goals to reduce military construction costs and timelines, the Army did not know to what extent the goals were met nor whether its military construction transformation strategy resulted in actual reductions in facility costs. Our review of selected project information showed that the Army did reduce the estimated cost of some facility construction projects and shortened building timelines during fiscal years 2007 through 2009, but it did not meet its overall stated goals. We also found that the Army did not consistently apply the cost reduction goal to all facility projects during fiscal years 2007 through 2009. Although the Army discontinued these numerical goals in 2010, Army officials believed its efforts to transform its military construction acquisition and building practices were successful in dampening the escalation of Army facilities' costs and would continue to help ensure cost-effective and timely facilities in future years.

The Army Set Goals to Reduce Construction Costs and Timelines but Did Not Monitor Its Level of Achievement

When the Army set goals to reduce construction costs and building timelines, it did not establish a framework for monitoring the achievement of these goals. Effective management practices call not only for setting program goals but also for monitoring goal achievement so that results can be measured and adjustments can be made to programs, if needed, to better achieve the goals. According to internal control standards for federal agencies, activities need to be established to monitor performance measures and indicators and managers need to compare actual performance to planned or expected results so that analyses of the relationships can be made and appropriate actions taken.[18] During our review, senior Army headquarters officials acknowledged that a framework to measure goal achievement should have been established when the cost and timeline goals were instituted. The officials also stated that the only explanation for not monitoring the goals was that they were so involved in implementing the many changes adopted under the Army's military construction transformation strategy that no one took the time to monitor and track the results being achieved from the changes.

The Army Did Not Subject All Facility Projects to the Cost Goal

During our review, we found that the Army did not subject all Army facility projects to its 15 percent cost reduction goal. According to Army officials, the Army planned to implement the cost goal by having project

[18]GAO, *Internal Control: Standards for Internal Control in the Federal Government*, GAO/AIMD-00-21.3.1 (Washington D.C.: Nov. 1999).

planners reduce the estimated cost of planned facilities by 15 percent, requesting funding from the Congress for the reduced amount, and then attempting to award and complete the project within the approved funding amount.[19] Thus, the cost goal was not directly related to actual facility costs but rather to estimated facility costs. However, all facility projects were not subjected to the reduction in estimated costs, as the following examples illustrate:

- For fiscal year 2007, Army officials stated that the 15 percent cost goal only applied to military construction facility projects that were budgeted for under the base realignment and closure program. Reductions were not required in the estimated costs of facility projects budgeted under the Army's regular military construction program. According to Army officials, reduced funding was not requested for the regular military construction program projects because the project estimates for the regular program were already complete before the reduction goal was announced, and the Army did not have sufficient time to recalculate the project estimates at the reduced amount before the budget request had to be submitted.

- For fiscal year 2008, Army officials stated that all Army facility cost estimates were subject to the 15 percent cost reduction goal, regardless of the funding source or type of facility. However, while all fiscal year 2008 projects were subject to the goal, Army officials stated that the 15 percent cost reduction in estimated costs was mandatory only for brigade, battalion, and company headquarters buildings, barracks, and dining facilities. For other types of facilities, if project planners believed that a 15 percent cost reduction could not be achieved when construction bids were ultimately solicited, the planners could submit a justification stating the reasons that a reduction was not made to the facility's estimated cost.

[19]To assist the services in preparing their military construction budget estimates, DOD issues military construction project cost estimating guidance each year. The guidance establishes a unit cost amount, such as $2,099 per square meter for a barracks to be built in fiscal year 2009, for the various facility types based on prior-year actual contract amounts. The military services are to use the guidance to estimate the cost of their planned military construction projects and then submit the estimates to the Congress for funding. Army officials stated that to implement its 15 percent cost reduction goal beginning in fiscal year 2007, the Army planned to reduce the unit cost amount contained in the DOD guidance by 15 percent, estimate the cost of its planned projects using the reduced unit cost amount, and then request the reduced project amount for funding in its budget request.

- For fiscal year 2009, Army officials stated that the 15 percent reduction goal was applied only to five specific types of facilities—brigade, battalion, and company headquarters buildings, barracks, and dining facilities. Cost estimates for all other types of facilities were not subjected to the goal. According to Army officials, general cost increases in the construction industry indicated that a 15 percent cost reduction could not be achieved for most fiscal year 2009 facilities. However, because of the changes incorporated under the Army's military construction transformation strategy, the officials believed that reductions could be achieved for the five specified facility types.

The Army Achieved Some Reductions in Estimated Costs but Did Not Meet Its Overall Goal

Because the Army had not monitored and thus did not know to what extent it had met its cost goal, we performed an analysis and found that, while the Army reduced the estimated cost and met its goal on some facility projects, it did not meet the goal on other projects. Specifically, we reviewed the construction cost estimates for a non-probability sample of 75 facility projects that were in the categories subject to the goal to determine whether a 15 percent reduction was taken in the estimated cost of the facilities, as reported in each facility's project justification. The 75 facilities included 15 fiscal year 2007 facilities funded under the base realignment and closure program, 30 projects from fiscal year 2008, and 30 projects from fiscal year 2009 for the five facility types subject to the goal. As shown in table 1, we found that the Army met its goal in 31 of the facilities (41 percent) and did not meet its goal in 44 of the facilities (59 percent). However, some reduction, but less than 15 percent, was made in the estimated cost of 24 of the 44 facilities that did not meet the goal. Although the Army had information on the actual costs of completed military construction projects, the Army did not routinely document the actual costs of the individual facilities included in the projects. For this reason, we could not determine whether any of these facilities resulted in actual savings compared to cost estimates based on DOD cost estimating guidance.

Table 1: Achievement of the Army's Cost Goal in Selected Projects

Fiscal year	Number of facilities reviewed	Facilities that met goal		Facilities that did not meet goal	
		Number	Percent	Number	Percent
2007	15	7	47	8	53
2008	30	10	33	20	67
2009	30	14	47	16	53
Total	**75**	**31**	**41**	**44**	**59**

Source: GAO analysis of DOD project justification data.

The following examples illustrate the achievement of the Army's cost goal in selected projects we reviewed:

- A fiscal year 2008 Army military construction project at Schofield Barracks, Hawaii, included a barracks. According to DOD military construction cost estimating guidance for that year, the project planners should have estimated $24.7 million for the cost of this barracks. However, according to the project's justification, the barracks' estimated cost was $20.9 million, which was the amount requested for funding. Because the barracks' estimated cost was about $3.8 million, or about 15 percent, less than the amount based on DOD guidance, the Army achieved its goal in this case.

- A fiscal year 2009 Army military construction project at Fort Lee, Virginia, included a dining facility. According to DOD military construction cost estimating guidance for that year, the project planners should have estimated $5.8 million for the cost of this facility. However, according to the project's justification, the dining facility's estimated cost was $5.4 million, which was the amount requested for funding. In this case, the facility's estimated cost was $400,000 (7 percent) less than the amount based on DOD guidance. Thus, the Army achieved some reduction in the estimated cost of this facility but did not meet the 15 percent goal.

- A fiscal year 2009 Army military construction project at Fort Stewart, Georgia, included a barracks. According to DOD military construction cost estimating guidance for that year, the project planners should have estimated $82.0 million for the cost for this facility. However, according to the project's justification, the barracks' estimated cost was $86.4 million, which was the amount requested for funding. In this case, the barracks estimated cost was about $4.4 million (5 percent) greater than the amount based on DOD guidance. Thus, the Army did not meet the 15 percent goal and actually requested more funding than it would have requested based on DOD guidance.

Army officials stated that the cost goal was not met in some projects because the projects' planners believed that a 15 percent cost reduction could not realistically be achieved when bids for the project were solicited because of local construction market conditions. In addition, the officials stated that, although the 15 percent goal might not have been achieved for all projects, they believed that the Army's efforts to transform its military construction acquisition and building practices were successful in dampening the escalation of Army facility costs.

The Army Shortened Some Building Timelines but Did Not Meet Its Overall Goal

Because the Army had not monitored and thus did not know to what extent it had met its 30 percent building timeline reduction goal, we performed an analysis to assess goal accomplishment and found that, while the Army shortened some building timelines, the overall goal was not achieved. Specifically, our analysis compared the actual average lapsed time between key building milestones for all completed projects approved during fiscal years 2007 through 2009 with the average lapsed times for the same milestones for completed projects approved in fiscal years 2004 through 2006—the 3 years before the implementation of the Army's military construction transformation strategy. To illustrate, one key Army building timeline measure is the lapsed time between the date that a project's design begins and the date that the project is ready for occupancy. As shown in table 2, we found that the Army's average lapsed time for this timeline measure was reduced by about 11 percent during fiscal years 2007 through 2009—an improvement, but less than the Army's 30 percent goal.

Table 2: Change in Average Army Building Timelines—Design Start to Ready for Occupancy

	Fiscal years 2004 to 2006 before the reduction goal		Fiscal years 2007 to 2009 after the reduction goal		Change in average lapsed days	
Project cost	**Number of projects**	**Average lapsed days**	**Number of projects**	**Average lapsed days**	**Number of days**	**Percent**
Less than $5 million	65	1,073	11	975	-98	-9
$5 million to $20 million	80	1,207	100	1,095	-112	-9
More than $20 million	81	1,649	194	1,229	-420	-25
All projects	**226**	**1,327**	**305**	**1,176**	**-151**	**-11**

Source: GAO analysis of Army project data.

Another key Army building timeline measure is the lapsed time between the date that the Army notifies the building contractor to begin construction and the date that the project is ready for occupancy. As shown in table 3, we found that the Army's average lapsed time for this timeline measure was reduced by about 5 percent during fiscal years 2007 through 2009—also an improvement, but also less than the Army's 30 percent goal.

Table 3: Change in Average Army Building Timelines—Construction Start to Ready for Occupancy

	Fiscal years 2004 to 2006 before the reduction goal		Fiscal years 2007 to 2009 after the reduction goal		Change in average lapsed days	
Project cost	Number of projects	Average lapsed days	Number of projects	Average lapsed days	Number of days	Percent
Less than $5 million	74	485	13	526	41	8
$5 million to $20 million	96	662	105	557	-105	-16
More than $20 million	89	858	203	700	-158	-18
All projects	**259**	**679**	**321**	**646**	**-33**	**-5**

Source: GAO analysis of Army project data.

Army officials stated that they were pleased that average building timelines had been reduced even if the 30 percent goal was not achieved.

The Army Discontinued Its Construction Cost and Timeline Reduction Goals in Fiscal Year 2010

During our review, Army officials stated that the Army decided to discontinue its construction cost and timeline reduction goals beginning in fiscal year 2010. The officials stated that, although the Army did not know to what extent cost and timeline reductions had been achieved, they believed that most of the cost and timeline reduction benefits from the Army's military construction transformation strategy had been obtained by the end of fiscal year 2009. The officials also stated that, although the specific cost and timeline goals were discontinued, the numerous changes made to the Army's facility acquisition and construction processes under the military construction transformation strategy would help ensure the continued delivery of cost-effective and timely facilities in the future.

Questions Remain about Whether the Use of Alternative Building Materials and Methods Will Yield Long-term Savings

DOD guidance allows the use of various building materials and methods and the Army appears to have achieved some savings in initial construction costs by expanding the use of wood materials and modular construction methods for some permanent facilities. However, DOD has not determined whether the use of these materials and methods also will result in savings over the long term compared to the traditional use of steel, concrete, and masonry materials and on-site building methods.

DOD Guidance Permits the Use of Various Building Materials and Methods

Over the past several years, DOD has taken several steps to bring uniformity among the military services in the criteria, standards, and codes used to design and construct military facilities. This has included the development of DOD's unified facilities criteria and unified facilities guide specification system of guidance for the design, construction, sustainment, restoration, and modernization of all DOD facilities.[20] For example, in 2007, DOD issued guidance—the Unified Facilities Criteria 1-200-01, "General Building Requirements"—which applies to the design and construction of all new and renovated facilities throughout DOD. The guidance states that the 2006 International Building Code, with some modifications and exceptions, is the building code for DOD. Among other things, the International Building Code defines several allowable types of construction based, in part, on the materials used in the construction and the materials' potential to be a fuel source in case of a fire. For example, type I and type II construction use materials such as steel, concrete, and masonry that, in accordance with applicable testing standards, are classified as noncombustible. Type V construction allows the use of various materials, including combustible materials, and typically includes facilities built with wood framing. Although the code allows the use of many construction materials, the military services have traditionally used types I and II construction consisting of steel, concrete, and masonry when building permanent common facilities, such as administrative buildings, barracks, and dining facilities. Appendix II contains further details on DOD's building materials and methods, including descriptions of types III and IV construction.

Substantial Quantitative Information Is Lacking on the Relative Merits from the Use of Alternative Construction Materials and Methods

During our review, we identified little quantitative information that compared the relative merits and economic impacts from the use of wood materials and modular construction methods with steel, concrete and masonry materials and on-site construction methods. The Army's decision to expand its consideration and use wood materials and modular construction for some permanent facilities was primarily based on the Army's desire to reduce military construction costs and building timelines in view of the significant increase in the Army's construction requirements beginning in fiscal year 2006. According to Army officials, the Army

[20]See *DOD Standard Practice for Unified Facilities Criteria and Unified Facilities Guide Specifications* (Military Standard 3007F, Dec. 13, 2006). The Standard Practice states that unified facilities criteria and unified facilities guide specifications are developed jointly by the Army, Navy, Marine Corps, Air Force, and other defense agencies and apply to all DOD components.

believed that the increased use of wood framing and modular construction would reduce initial construction costs and building timelines for new facilities, result in facilities that met the Army's needs, and also result in lower facility life-cycle costs. However, the Army did not have substantial quantitative information or analyses to support its view on lower life-cycle costs. For example, according to Army officials, the Army had performed only two analyses that compared the life-cycle costs of permanent facilities built with alternative construction materials and building methods. One analysis compared the life-cycle cost of a barracks built with wood materials with the life-cycle costs of a similar barracks built with steel, concrete, and masonry. Although this analysis estimated that the barracks constructed with wood would have lower life-cycle costs, the analysis was not based on actual costs. Instead, the analysis used cost estimates which might or might not provide a reliable prediction of actual costs over the long term. In addition, our review of the analysis found other flaws and data errors, such as understating the square footage of one of the projects by 39 percent, which affected the outcome of the analysis and cast further doubt on the reliability of the analysis. The other Army analysis assessed life-cycle costs for several types of construction materials and methods. However, it also was not based on actual costs but rather on estimates obtained in planning documents.

The Navy and the Air Force generally disagreed with the Army's views on the benefits from expanded use of wood materials and modular building methods. Senior officials with the Naval Facilities Engineering Command and the Air Force Center for Engineering and the Environment stated that they believed that use of wood materials and modular methods instead of steel, concrete, and masonry would result in facilities with shorter service lives and higher, not lower, life-cycle costs. To illustrate, the officials noted that features sometimes used in wood-frame construction could result in higher maintenance costs. For example, a wood-frame building finished with a shingle roof might have higher maintenance costs over the long term compared to a building finished with a steel roof because the shingles would have to be replaced periodically over the life of the building. While their views differed with the Army, Navy and Air Force officials stated that they had little quantitative support for their views and had performed no analyses that compared the long-term costs of facilities built with wood materials versus steel, concrete, and masonry materials.

During our visits to private organizations that represented the interests of wood, modular building, and concrete and masonry industries, we found various views and opinions on the long-term merits and economic benefits from the use of alternative construction materials and building methods.

However, we did not find documented analyses comparing the actual life-cycle costs of facilities constructed with alternative materials and methods.

Wood-Frame Construction Can Result in Lower Initial Construction Costs

To gain some insight into the economic merits of the Army's increased use of wood materials and modular construction, we reviewed available information related to initial facility construction costs depending on the materials and methods used to construct new buildings. We found evidence that the use of wood-frame construction can result in lower initial building costs. For example, we found that the Army apparently had achieved construction cost savings by using wood-frame construction in several barracks projects that were initially designed to be built with steel, concrete, and masonry. To illustrate, according to Army officials, a fiscal year 2006 project at Fort Carson to construct a barracks and company operations facility was estimated to cost about $35 million based on actual contract bids and the use of steel, concrete, and masonry construction. After switching the barracks' design to wood-frame construction and resoliciting the project, the officials stated that the project was subsequently awarded for about $24 million, a savings of about $11 million, or 31 percent in estimated costs (see fig. 2).

Figure 2: Wood-Frame Barracks at Fort Carson, Colorado

Source: GAO.

Note: Photograph on left shows exterior of the barracks and the photograph on right shows an interior corridor.

Similarly, a fiscal year 2001 barracks project at Fort Meade, Maryland, called for the construction of eight three-story barracks buildings with a total of 576 private sleeping rooms. On the basis of the project's initial design using steel, concrete, and masonry, the Army estimated that the project would cost about $48 million, which was more than the amount approved for the project. In an effort to reduce the cost, the project was redesigned to specify the use of wood materials and residential construction practices. Subsequently, the project was constructed at a cost of about $39 million, or about $9 million (19 percent) less than the original estimated cost (see fig. 3).

Figure 3: Wood-Frame Barracks at Fort Meade, Maryland

The project under construction using wood materials in 2003

A portion of the completed project

Source: GAO.

Note: Photograph on left shows the project under construction using wood materials in 2003 and the photograph on right shows a portion of the completed project.

Sources outside of DOD also have noted that the use of wood-frame construction can result in lower initial building costs. For example, an August 2009 building valuation guide published by the International Code Council reported that the use of residential building methods, including wood-frame construction, for several types of facilities resulted in a 19 percent to 25 percent construction cost savings compared to the use of commercial construction methods, including the use of steel, concrete,

and masonry materials.[21] Also, a 2005 study collected information from cities across the United States to develop a construction cost model to accurately evaluate the relative construction costs of a multifamily building constructed using five different construction materials. Information collected during the study showed that the use of wood-frame construction could result in an average 6 percent to 7 percent construction cost savings compared to the use of masonry construction.[22]

Some Information Suggests That the Use of Wood Building Materials Might Result in Lower Long-term Costs

Although we found little quantitative information on the long-term economic merits from the use of alternative building materials and methods, we found some evidence suggesting that the long-term costs of facilities built with wood-frame materials might result in lower or equal long-term costs compared to similar facilities built with steel, concrete, and masonry materials. For example, we reviewed the annual maintenance costs associated with two wood-frame barracks projects constructed in 2003 and 2006 at Fort Meade and Fort Detrick, Maryland, respectively. These facilities are the Army's initial two modern, permanent barracks constructed with wood frame. During fiscal years 2007 and 2008, the annual maintenance costs of the wood-frame barracks on a square-foot basis was significantly less than the annual maintenance costs of other barracks at each installation constructed with steel, concrete, and masonry methods. However, the wood-frame barracks were newer by several years compared to the concrete and masonry barracks, which could account for the difference in maintenance costs. Still, local officials responsible for barracks maintenance at each installation stated that based on experience to date they believed that even in the long term the annual maintenance costs of the wood-frame barracks would be no greater than the annual maintenance costs of the installations' concrete and masonry barracks.

As another illustration, we visited two privatized housing projects for unmarried servicemembers where service officials stated that private developers were responsible for constructing, owning, operating, and

[21]International Code Council, *Building Valuation Data* (Washington, D.C., Aug. 2009).

[22]See *Fire Safe Construction Cost Comparison Study: Executive Summary Report* (Commission Number 05119, Nov. 2, 2005), sponsored by New England/New York Fire Safety Construction Advisory Council, Pennsylvania Fire Safe Construction Advisory Council, Mid-Atlantic Fire Safety Construction Advisory Council, and Northeast Cement Shippers Association.

maintaining the housing for 50 years in one case and 46 years in the other. During each visit, the developers stated that wood-frame construction was being used because the developers believed that, based on their internal long-term cost analyses, this type of construction would result in the most economical project over the long term. For example, the Navy partnered with a developer to build a pilot privatized housing project for unaccompanied personnel in the Norfolk, Virginia, area. The project includes the construction of 755 rooms in a six-story midrise building and 435 rooms in 87 separate housing units. The developer stated that the midrise building used noncombustible materials, such as concrete, and the 87 separate housing units used wood-frame materials.[23] The developer stated that the type of construction used for each type of building was based on the most cost-effective type of construction, considering life-cycle costs, to provide the lowest total cost over a 50-year period. Further, the developer also stated that, because the exterior surfaces and interior finishes for both the midrise building and separate housing units were very similar, no difference in operation and maintenance costs was anticipated with regard to the different types of construction (see fig. 4).

[23]According to the International Building Code, buildings over four stories must be constructed with noncombustible materials, such as steel, concrete, and masonry.

Figure 4: Privatized Unaccompanied Personnel Housing Project in Norfolk, Virginia

A midrise building being constructed with noncombustible materials

A separate housing unit built with wood-frame construction

Source: GAO.

Note: Photograph on the left shows a midrise building being constructed with noncombustible materials and the photograph on right shows a separate housing unit built with wood-frame construction.

In the other project visited, the Army had partnered with a developer to build, own, and operate a privatized housing project for senior unmarried servicemembers at Fort Bragg, North Carolina, for 46 years. The project includes 13 apartment-style buildings with a mix of 312 one- and two-bedroom apartments. The developer stated that wood-frame construction was used in the project because, compared to the use of noncombustible materials and building methods, wood-frame construction resulted in lower initial construction costs and, based on the developer's long-term analyses, was expected to also result in lower life-cycle costs (see fig. 5).

Figure 5: Privatized Senior Unaccompanied Personnel Housing Project at Fort Bragg, North Carolina

Source: GAO.

Note: The photographs show exterior and interior views of the housing built with wood-frame construction.

Questions Remain about the Service Life and Durability of Facilities Constructed with Wood Materials and Modular Methods

Determining the relative merits and economic impacts of alternative building materials and methods over the long term requires the consideration of possible differences in facility service life and durability resulting from the use of different building materials and methods. Although we found no DOD studies or definitive analyses assessing possible service life and durability differences and any associated impact on life-cycle costs, we discussed opinions on the issue with service headquarters officials and local officials at five Army installations we visited.

Army, Navy, and Air Force headquarters officials expressed the opinion that steel, concrete, and masonry facilities generally had longer service lives and were more durable than wood-frame facilities. However, we found that the services had different opinions on the importance of durability. For example, although Army officials agreed with the opinion of Navy and Air Force officials that the use of steel, concrete, and masonry generally resulted in more durable facilities, the Army's opinion differed from the other services' opinions on whether greater durability also meant that such facilities were more desirable. Army officials stated that because missions, requirements, and standards change over time, facilities constructed today will be outdated in 20 to 25 years and will require major

renovation or possibly conversion to other uses to meet needs in the far outyears. Thus, Army officials stated that considering facility use beyond 25 years is not productive and facilities built with wood-frame materials and modular building methods will meet the Army's needs even if they do not last as long as facilities constructed with steel, concrete, and masonry.

Officials at the Army installations we visited had various opinions on the expected service life and durability of facilities constructed with wood materials and modular building methods. Officials at Fort Meade and Fort Detrick, for example, stated that they were satisfied with the durability of wood-frame barracks constructed on-site at their installations and would not seek to use steel, concrete, and masonry even if they had the opportunity to rebuild the facilities.

With respect to wood modular construction, we found the following concerns expressed by officials at Fort Bliss and Fort Carson:

- Fort Bliss officials noted that because modular units were constructed off-site and then transported in some cases over 1,000 miles to the installation for assembly, the vibrations experienced during transportation might affect the units' structures and result in durability issues. The modular industry, however, contends that modular units are constructed to withstand such transportation stresses.

- Fort Carson officials expressed concern that temperature changes would cause the expansion and contraction of the joints where modular units were joined, which might adversely affect durability in the long term.

- Fort Bliss and Fort Carson officials expressed concerns that settling of the different sections of modular facilities might show stress where they join together, resulting in additional maintenance requirements in the long term.

- Officials at Fort Bliss and Fort Carson also said that reconfiguring modular-built facilities for other uses, if needed in the future, might be more difficult compared to wood-frame facilities built on-site, and thus result in a shorter facility service life.

Figure 6 shows a Fort Bliss barracks under construction using modular building methods.

Figure 6: Use of Modular Construction to Build a Barracks at Fort Bliss, Texas

Source: GAO.

Note: Photographs beginning with top left: modular-constructed units on transportation trailer, moving units from trailers, barracks foundation ready for unit placement, assembled units before exterior finishing, exterior of nearly completed barracks, interior hallway of completed barracks.

Fort Bliss officials added that, although they had some concerns about the durability of modular construction, the use of modular construction methods resulted in faster building timelines compared to steel, concrete, and masonry construction, which would help ensure the timely

completion of facilities needed to accommodate the large number of soldiers reporting to the installation over the next few years.

Although officials at some installations we visited expressed concerns over the durability of facilities built with modular building methods, other sources have reported information that supports the durability of modular facilities. For example, after Hurricane Andrew hit Florida in 1992, a team from the Federal Emergency Management Agency conducted a study of various building types and how well they weathered the storm. On the basis of its observations, the team concluded that, in general, both masonry buildings and wood-framed modular buildings performed relatively well.[24]

Conflicts Exist between Antiterrorism Building Standards and Sustainable Goals, but the Services Consider the Conflicts to Be Manageable

Although there are areas of conflict when designing facilities that meet both antiterrorism construction standards and sustainable design goals, military service officials stated that the conflicts are considered to be manageable and not a significant obstacle to the design and construction of new facilities. Service officials noted, however, that achieving higher levels of sustainability in future construction projects while still meeting the antiterrorism standards would further increase initial facility costs and create additional design challenges.

DOD Has Recognized and Routinely Manages the Conflicts between Antiterrorism Building Standards and Sustainable Design Goals

DOD has recognized that areas of conflict exist between DOD's antiterrorism building standards and sustainable design goals and has developed approaches to help deal with the conflicts. To illustrate, military service officials noted that the antiterrorism mandatory building standard to provide standoff distances around new facilities to keep potential explosives at a distance reduces development density and conflicts with a sustainable design goal to increase development density. Similarly, some officials stated that sustainable design goals related to

[24]See Federal Emergency Management Agency and the Federal Insurance Administration, *Building Performance: Hurricane Andrew In Florida Observations, Recommendations, and Technical Guidance, FIA-22* (Washington, D.C., Dec. 21, 1992).

greater use of windows to increase natural lighting conflicts with the recommended antiterrorism building measure related to minimizing hazards from flying glass fragments from windows.

To help deal with such conflicts, a facility planning tool was developed that identifies and addresses the potential conflicts from integrating required antiterrorism standards with sustainable design goals. The tool uses a color-coded matrix to identify the relationship between the antiterrorism standards and sustainable design goals. Conflicting or possibly conflicting relationships are coded red and yellow, respectively, and the tool provides additional information to aid project designers in dealing with these areas.

The services do not consider the conflicts between antiterrorism building standards and sustainable goals to be a significant obstacle when designing and building new military facilities. Service officials stated that with use of the facility planning tool and a comprehensive design approach, project designers are able to develop successful building solutions that ensure both secure and high-performance facilities. In particular, officials in each military service stated that the services had set a goal that beginning in fiscal year 2009 all new major military construction buildings would be designed and constructed to be silver-level certifiable under the U.S. Green Building Council's Leadership in Energy and Environmental Design Green Building Rating System. This 100 percent goal was higher than the DOD-wide goal for fiscal year 2009, which called for 70 percent of new buildings to be silver-level certifiable.[25] Further, service officials stated that in some cases military buildings have been constructed that met the rating system's next higher sustainable design level—the gold level—while still complying with all antiterrorism standards. However, service officials also noted that achieving higher levels of sustainability while still meeting all antiterrorism standards increases initial facility costs and creates additional design challenges.

To obtain additional details on how the services were dealing with the conflicts between the standards and the goals, we followed up with the project planners responsible for 90 military construction projects from a non-probability sample of Army, Navy, and Air Force projects approved during fiscal years 2007 through 2009. According to the planners, 80 of the

[25]We did not determine the extent to which these goals were met because it was outside the scope of our review.

90 projects (89 percent) required no special steps or workarounds to meet both antiterrorism standards and sustainable design goals. For the projects where special steps or workarounds were needed, most issues related to facility windows and the required building standoff distances. For example, the planners of a fiscal year 2007 child development center at Fort Lewis, Washington, reported that special steps or workarounds were needed to simultaneously meet antiterrorism standards and sustainable goals. According to the planners, both the child care program and sustainable design goals encouraged large window areas on the exterior of the building for daylighting and child-height window views on both the building's exterior and interior. However, the antiterrorism standards and recommendations encourage reduced window sizes with specific window glazing techniques to minimize hazards from flying glass fragments and the use of reflective glazing to prevent views of a building's interior. The planners stated that an acceptable design solution was developed, but the result significantly increased the cost of the facility's windows.

Although the project planners stated that 80 of the 90 projects in our sample required no special steps or workarounds to meet both antiterrorism standards and sustainable design goals, the planners also reported that in some cases meeting both the standards and goals resulted in additional land use, community decentralization, or installation development sprawl.[26] Specifically, project planners reported that, primarily because of the required standoff distances around new facilities, 18 (20 percent) of the 90 projects we reviewed resulted in additional land use, community decentralization, or installation development sprawl. For example, planners of a fiscal year 2008 instruction building at Fort Huachuca, Arizona, reported that because of the antiterrorism standoff distance standard, the building site was approximately 50 percent larger than required if there were no standoff requirements. Similarly, project planners of a fiscal year 2009 unit maintenance facilities project at Fort Campbell, Kentucky, stated that complying with the antiterrorism standoff distance standard resulted in additional land use, including the construction of an additional parking lot situated across the street from the facilities.

[26]See note 7.

Antiterrorism Building Standards and Sustainable Design Features Add to Facility Construction Costs

According to service officials, incorporating antiterrorism standards in new facilities typically adds about 1 to 5 percent to construction costs and incorporating sustainable design building features typically adds about 2 percent to construction costs. The officials noted, however, that each project is unique and the estimated cost to incorporate antiterrorism standards and sustainable design features can vary significantly among military construction projects.

To obtain additional details on the costs of incorporating antiterrorism standards and sustainable design features in new facilities, we reviewed information contained in the project justifications for the 90 military construction projects included in our non-probability sample of Army, Navy, and Air Force projects approved during fiscal years 2007 through 2009. The review showed that the average estimated cost to incorporate antiterrorism standards in the projects was about 2.0 percent of a project's total cost with the range varying from 0.3 percent to 6.6 percent.[27] The review also showed that the average estimated cost of the sustainable design features was about 1.6 percent of a project's total cost with the range varying from 0.7 percent to 2.6 percent.[28] According to the project planners, the actual costs of incorporating antiterrorism standards and sustainable design features in new projects was not available because contractors normally do not separately identify these costs in their bids responding to solicitations for project construction.

Conclusions

Although the Army appears to have achieved some savings in initial construction costs by expanding the use of wood materials for some permanent facilities, the military services had little quantitative information on whether the use of wood materials and modular building methods will also result in lower long-term costs compared to the traditional use of steel, concrete, and masonry materials and on-site building methods. Determining the relative merits and economic impacts from the use of alternative construction materials and methods is an

[27]Two of the 90 project justifications did not separately identify the estimated cost of the antiterrorism features included in the projects' total cost. Thus, the average and range of percentages is for the 88 project justifications that did separately identify the estimated cost of the antiterrorism features.

[28]Project justifications did not begin to provide separate estimates of the cost to incorporate sustainable design features until fiscal year 2009. Thus, the average and range of estimated sustainable costs reflects the 30 fiscal year 2009 projects included in our sample.

important issue for the military services to resolve to help ensure that DOD's military construction program meets requirements at the lowest cost over the long term. Unless the services perform additional study and analysis to determine the relative merits and long-term economic impacts from the use of alternative construction materials and methods, DOD will not know whether the use of wood materials and modular building methods will result in the most economical long-term building solution or whether DOD's unified facilities criteria, or other military construction program guidance, needs to be changed so that new facilities are constructed with materials and methods that meet requirements at the lowest cost over the long term.

Recommendations for Executive Action

To address unanswered questions about the merits and long-term costs from the use of alternative construction materials and methods for new common facilities, such as administrative buildings and barracks, we recommend that the Secretary of Defense direct the Deputy Under Secretary of Defense (Installations and Environment) to commission a tri-service panel that would be responsible for determining and comparing the estimated life-cycle costs of facilities built with alternative construction materials and methods, including a mix of wood and steel, concrete, and masonry construction materials and on-site and modular construction methods.

We also recommend that the Deputy Under Secretary of Defense (Installations and Environment) use the results from the tri-service panel's determinations to revise DOD's unified facilities criteria or other appropriate military construction guidance, as deemed appropriate, to ensure that new facilities are constructed with the materials and methods that meet requirements at the lowest cost over the long term.

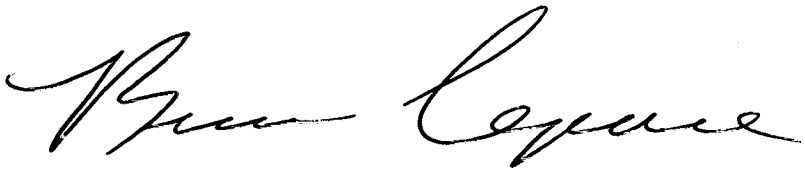
Agency Comments and Our Evaluation

Officials from the Office of the Deputy Under Secretary of Defense (Installations and Environment) provided oral comments on a draft of this report. In the comments, DOD stated that it agreed with our recommendation to commission a tri-service panel that would be responsible for determining and comparing the estimated life-cycle costs of facilities built with alternative construction materials and methods. DOD stated that the department needed to better understand the life-cycle cost implications of different building materials and methods and to use this knowledge in evaluating and comparing total life-cycle cost alternatives. In view of the questions raised during the course of our review, DOD stated that it had already initiated a tri-service panel to

develop a template that will objectively evaluate the relative life-cycle costs between competing construction proposals in the facilities acquisition process. When complete, the template is expected to allow prospective project designers to propose alternative construction materials and methods, among other design considerations, to achieve lower life-cycle costs or best overall value. DOD stated that this approach would recognize that the department cannot be solely responsible for determining the life-cycle cost implications of each possible alternative and needs to consider the best available industry knowledge, expertise, and innovation for any particular facility requirement. Nonetheless, DOD stated that it expects to monitor the performance of alternative materials and methods to better inform this process over time. We believe that DOD's actions, once implemented, will address the intent of the recommendation.

DOD stated that it partially agreed with our recommendation that the department use the results of the tri-service panel's determinations to revise DOD's unified facilities criteria or other appropriate military construction guidance, as deemed appropriate, to ensure that new facilities are constructed with the materials and methods that meet requirements at the lowest cost over the long term. DOD stated that it agreed with the general concept that lessons learned should be incorporated into facilities criteria and specifications to the extent practical. However, DOD also stated that in some cases, such as to minimize adverse environmental impacts, facilities might be built with materials or methods that do not result in the lowest cost but in the best value for the department. In short, DOD stated that the use of the lowest-cost materials and methods should be an important consideration in facilities acquisition, but not the overriding goal. Our recommendation was not intended to restrict DOD in its efforts to achieve the best value, but rather to ensure adequate consideration of the long-term merits and economic impacts from building alternatives. We continue to believe that when all costs are considered over the long term, including environmental costs, the best value to DOD will normally be the construction alternative with the lowest life-cycle cost. Further, as stated in our recommendation, when revising its construction guidance based on the tri-service panel's determinations, we believe that DOD should only make revisions that it deems to be appropriate. As a result, we believe DOD's plan to incorporate the tri-service panel's findings into its guidance will address the intent of the recommendation.

We are sending copies of this report to the Secretary of Defense; the Secretaries of the Army, the Navy, and the Air Force; the Commandant of the Marine Corps; and the Director, Office of Management and Budget. In addition, the report will be available at no charge on the GAO Web site at http://www.gao.gov. If you or your staff have any questions on the information discussed in this report, please contact me at (202) 512-4523 or leporeb@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix V.



Brian J. Lepore, Director
Defense Capabilities and Management

Appendix I: Scope and Methodology

To assess the Army's measurement and achievement of its military construction cost and timeline reduction goals, we interviewed Army headquarters and U.S. Army Corps of Engineers officials and reviewed applicable documentation concerning the Army's military construction transformation strategy and the associated establishment and implementation of the Army's goals to reduce construction costs and building timelines. We also reviewed guidance for internal controls and effective management practices that call for the monitoring of performance goals and discussed with Army officials the reasons that the Army did not establish a framework to monitor the achievement of its construction cost and building timeline reduction goals. To obtain some insight into the Army's accomplishment of its cost goal, we reviewed the construction cost estimates for a non-probability sample of 75 facility projects to determine whether a 15 percent reduction was taken in the estimated cost of the facilities, as called for according to the Army's plan for implementing the goal. We selected projects for review from a list of all Army military construction projects approved during fiscal years 2007 through 2009. The projects selected represented a range of facility types and geographic locations and were in the categories of facilities subject to the cost reduction goal. More specifically, the 75 facilities included 15 fiscal year 2007 facilities funded under the base realignment and closure program, 30 projects from fiscal year 2008, and 30 projects from fiscal year 2009 for five facility types subject to the goal. The construction cost estimates were included in the project justifications submitted to the Congress as part of the Army's funding request. To obtain some insight into the Army's accomplishment of its building timeline goal, we used actual Army project timeline information to compare the average lapsed time between key building milestones for all completed projects approved during fiscal years 2007 through 2009 with the lapsed times for the same milestones for completed projects approved in fiscal years 2004 through 2006—the 3 years before the implementation of the Army's military construction transformation strategy. Although we did not independently validate the Army's building timeline data, we discussed with the officials steps they had taken to ensure reasonable accuracy of the data. As such, we determined the data to be sufficiently reliable for the purposes of this report.

To evaluate the merits and economic impacts from the Army's expanded use of wood materials and modular building methods for permanent facilities, we interviewed Office of the Secretary of Defense, Army, Navy, and Air Force officials and reviewed related documentation, policies, and construction guidance on the use of construction materials and building methods for military facilities. We also discussed how various

construction materials and building methods could affect initial construction costs, long-term costs, service life, and durability of new military facilities and reviewed available documentation on the issue from the U.S. Army Corps of Engineers, the Naval Facilities Engineering Command, the Air Force Center for Engineering and the Environment, and from representatives of three industry groups—the American Wood Council, the Modular Building Institute, and the National Concrete and Masonry Association. To observe the use of alternative construction materials and methods and discuss the issue with local military officials, we visited five Army installations—Fort Bliss, Texas; Fort Bragg, North Carolina; Fort Carson, Colorado; Fort Detrick, Maryland; and Fort Meade, Maryland—where wood materials or modular building methods had been used to construct permanent facilities. During the visits, we obtained opinions and reviewed available information on the relative merits and economic impacts from using alternative construction materials and building methods. We also met with the developers of two military privatized unaccompanied personnel housing projects to discuss the reasons that the building materials and methods used in the projects were chosen. One privatized project was associated with the Navy and was located in the Norfolk, Virginia, area and the other project was associated with the Army and was located at Fort Bragg, North Carolina.

To review potential conflicts between antiterrorism construction standards and sustainable design goals and the costs to incorporate the standards and goals in new facilities, we reviewed applicable Department of Defense (DOD) policies, guidance, goals, and costs related to incorporating antiterrorism construction standards and sustainable design goals in new military facilities. We also interviewed officials at the Office of the Secretary of Defense, the U.S. Army Corps of Engineers, the Naval Facilities Engineering Command, and the Air Force Center for Engineering and the Environment concerning how potential conflicts between the standards and the goals are identified and addressed and how incorporating the standards and goals affects the cost of new facilities. To obtain additional details on how the services were dealing with potential conflicts between the standards and the goals, we followed up with the project planners responsible for 90 military construction projects selected from a non-probability sample of Army, Navy, and Air Force projects approved during fiscal years 2007 through 2009. We selected projects for review from a list of all Army, Navy, and Air Force military construction projects approved during fiscal years 2007 through 2009. We also selected projects to represent a range of facility types and geographic locations and included 10 Army, 10 Navy, and 10 Air Force projects approved in each of the three fiscal years—for a total of 30 projects approved in each fiscal

year. During the follow up, we asked the project planners whether the projects required any special steps or workarounds to meet both antiterrorism standards and sustainable design goals and whether the projects resulted in additional land use, community decentralization, or installation development sprawl. We did not independently verify the information provided by the project planners. In addition, to obtain additional details on the costs of incorporating antiterrorism standards and sustainable design features in new facilities, we reviewed information contained in the project justification of each of the 90 projects. The justifications included the estimated cost to incorporate antiterrorism standards in the project and, for fiscal year 2009 projects, the justifications also included the estimated cost to incorporate sustainable design goals.

We conducted this performance audit from March 2009 to February 2010 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: DOD Construction Practices

In 2007, DOD issued guidance—the Unified Facilities Criteria 1-200-01, *General Building Requirements*—that applies to the design and construction of all new and renovated facilities throughout DOD. The guidance adopted the 2006 International Building Code, with some modifications and exceptions, as the building code for DOD. The International Building Code defines allowable types of construction based on factors such as the size, configuration, and planned facility use and categorizes planned buildings into five construction types. The construction type classifications are based on the fire-resistive capabilities of the predominant materials used in the construction progressing from type I, the most fire-resistive, to type V, the least fire-resistive. More specifically, types I and II construction incorporate materials such as steel, concrete, and masonry which, in accordance with applicable testing standards, are classified as noncombustible. Types III and V construction incorporate the use of any material permitted by the code to include combustible materials such as wood products and plastics. Type IV construction is related to the use of heavy timber. Table 4 illustrates the materials that are allowed to be used in the building elements—i.e., the structural frame, bearing walls, nonbearing walls, floor, and roof—of a facility built according to each type of construction.

Table 4: Types of Construction and Materials Allowed by the International Building Code

	Building element and permitted material				
Type[a]	**Structural frame**	**Bearing walls**	**Nonbearing walls**	**Floor construction**	**Roof construction**
I & II	Noncombustible[b]	Noncombustible	Noncombustible	Noncombustible	Noncombustible
III	Any material permitted by code	Exterior walls are noncombustible Interior elements are any material permitted by code	Exterior walls are noncombustible Interior elements are any material permitted by code	Any material permitted by code	Any material permitted by code
IV	Heavy timber	Exterior walls are noncombustible	Heavy timber	Heavy timber	Heavy timber
V	Any material permitted by code	Any material permitted by code	Any material permitted by code	Any material permitted by code	Any material permitted by code

Source: GAO analysis of the International Building Code.

[a]Dependent upon a building's planned use and occupancy, a building's height, floor area, and total area are restricted by the type of construction used. In general, Type I construction is the least restricted and Type V is the most restricted, per Section 503 of the International Building Code.

[b]Noncombustible materials are to be tested in accordance with methods established by the American Society for Testing and Materials, per Section 704 of the International Building Code. Noncombustible materials include but are not limited to concrete, masonry, and steel.

In each of the construction types, the intended level of fire protection is achieved by assembling building elements to achieve fire-resistance ratings established by the International Building Code.[1] In a type I steel-frame building, for example, spray-applied fire-resistive material can be used to enable the structural frame to achieve the 3-hour fire-resistance rating required by the code, and in a type V wood-frame building, covering exposed wood with drywall allows the affected building elements to achieve the 1-hour fire-resistance rating required by the code. In addition to the fire protection provided by the assembly of building elements, the code establishes requirements for use of automatic fire sprinkler systems based on factors to include the planned use and size of a facility and the planned number of occupants.

The International Building Code also serves to limit building size based on the level of fire protection provided by its construction. Because type I construction is the most fire-resistive of the construction types, the code places minimal limits on the dimensions of type I buildings. To account for the comparatively lower level of fire protection provided by type II through type V construction types, the code establishes limits on building dimensions. For example, a type V barracks building that is protected with an automatic sprinkler system is limited under the code to a maximum height of 4 stories, or 60 feet, with each story having maximum floor area of 36,000 square feet.

DOD has traditionally built permanent buildings using on-site construction where materials are delivered to the construction site and the materials are then assembled into a finished facility. However, as part of its military construction transformation strategy, the Army has allowed, among other alternative construction techniques, the use of modular construction. In this method of construction, building sections are fabricated off-site in a factory environment, transported to the construction site, and then connected to other building sections to assemble the facility. Although some on-site construction is normally needed to complete the facility, the Modular Building Institute reports that in a typical modular construction project between 80 and 95 percent of the total construction is completed at an off-site factory. Because the off-site construction can proceed under controlled conditions at the same time that on-site foundation and other

[1]Fire-resistance rating is the period of time, expressed in hours, that a building element, component, or assembly maintains the ability to confine a fire and retain its structural integrity. Fire ratings are assigned on the basis of testing standards promulgated by the American Society for Testing and Materials.

work is being completed, modular construction projects can potentially be completed with less material waste and in less time compared to projects built with on-site construction methods.

Appendix III: DOD's Antiterrorism Construction Standards

DOD's minimum antiterrorism construction standards are contained in DOD's Unified Facilities Criteria 4-010-01, DOD Minimum Antiterrorism Standards for Buildings. The standards include 22 mandatory standards and 17 recommended, but not required, measures designed to mitigate antiterrorism vulnerabilities and terrorist threats in inhabited buildings. Mandatory standards 1 through 5 are considered site planning standards. These standards note that operational, logistic, and security requirements must be integrated into the overall design of buildings, equipment, landscaping, parking, roads, and other features and that the most cost-effective solution for mitigating explosive effects on buildings is to keep explosives as far as possible from the buildings. Standards 6 through 9 are considered structural design standards. These standards require that additional structural measures be incorporated into building designs to ensure that buildings do not experience progressive collapse or otherwise experience disproportionate damage even if required standoff distances can be achieved. Standards 10 through 15 are considered architectural design standards. These standards cover many aspects of building layout that must be incorporated into designs to improve overall protection of personnel inside buildings. Standards 16 through 22 are considered electrical and mechanical design standards. These standards address limiting damage to critical infrastructure; protecting building occupants against chemical, biological, and radiological threats; and notifying building occupants of threats or hazards. Concerning the 17 recommended measures, DOD states that incorporating these measures can enhance site security and building occupants' safety with little increase in cost and should be considered for all new and existing inhabited buildings. Table 5 provides a brief summary description of each mandatory standard and recommended measure.

Table 5: DOD's Antiterrorism Construction Standards

Mandatory standards	Brief description
1. Standoff distances	Specified standoff distances must be coupled with appropriate building hardening to provide the necessary level of protection to building occupants.
2. Unobstructed space	Ensure that obstructions within 33 feet of inhabited buildings do not allow for concealment of explosive devices from observation.
3. Drive-up/drop-off areas	Ensure that, where required, drive-up or drop-off areas are clearly defined and marked and prevent parking of vehicles in those areas.
4. Access roads	Ensure that control measures are implemented to prohibit unauthorized use of necessary access roads, including those required for fire department access.
5. Parking	Eliminate parking beneath inhabited buildings or on rooftops of inhabited buildings.
6. Progressive collapse avoidance	Design the superstructure of inhabited buildings of 3 stories or more to sustain local damage with the structural system as a whole remaining stable.
7. Structural isolation	Design all additions to existing buildings to be structurally independent from the adjacent existing building.
8. Building overhangs	Avoid building overhangs with inhabited spaces above them where access is possible to the area underneath the overhang.
9. Exterior masonry walls	Unreinforced masonry walls are prohibited for the exterior walls of new buildings.
10. Windows and skylights	Take various measures to minimize hazards from flying glass fragments from windows and skylights.
11. Building entrance layout	Ensure that the main building entrance does not face an installation perimeter or other uncontrolled vantage points with direct lines of sight to the entrance.
12. Exterior doors	Ensure that all exterior doors into inhabited areas open outwards.
13. Mail rooms	Locate mail rooms on the perimeter of the building and as far as possible from heavily populated areas of the building and critical infrastructure; ensure that mail rooms are well sealed to limit migration of airborne chemical, biological, and radiological agents.
14. Roof access	Control access to roofs to minimize the possibility of aggressors placing explosives or chemical, biological, or radiological agents there.
15.Overhead mounted architectural features	Ensure that overhead mounted features above a specified weight are mounted to minimize the likelihood that they will fall and injure building occupants.
16. Air intakes	Locate all outside air intakes that distribute air throughout the building at least 10 feet above the ground.
17. Mail room ventilation	Provide separate, dedicated air ventilation systems for mail rooms.
18. Emergency air distribution shutoff	Provide an emergency shutoff switch that can immediately shut down the air distribution system throughout the building.
19. Utility distribution and installation	Route critical or fragile utilities so that they are not on exterior walls or on walls shared with mail rooms; locate redundant utilities and emergency backup systems in a manner that will minimize the possibility that both systems will be adversely affected by a single event.
20. Equipment bracing	Mount all overhead utilities and other fixtures above a specified weight to minimize the likelihood that they will fall and injure building occupants.
21. Under building access	Ensure that access to crawl spaces, utility tunnels, and other means of under-building access is controlled.

Mandatory standards	Brief description
22. Mass notification	All inhabited buildings must have a timely means to notify occupants of threats and instruct them what to do in response to those threats.
Recommended measures	
1. Vehicle access points	Keep the number of vehicle access points around buildings to the minimum necessary.
2. High-speed vehicle approaches	Ensure that there are no unobstructed vehicle approaches perpendicular to inhabited buildings.
3. Vantage points	Identify and eliminate or mitigate vantage points outside the control of building personnel.
4. Drive-up/drop off areas	Locate drive-up/drop off areas away from large window areas of buildings.
5. Building location	Maximize separation distance between inhabited areas of buildings and areas with large visitor populations.
6. Railroad location	Avoid sites for inhabited buildings that are close to railroads.
7. Access for family housing	Provide space for controlling access at the perimeter of the housing area.
8. Standoff for family housing	Maintain a specified standoff distance from installation perimeters and roads external to housing areas.
9. Minimize secondary debris	Eliminate unreinforced barriers that are accessible to vehicle traffic.
10. Building separation	Ensure that that billeting, high occupancy family housing, and primary gathering buildings are separated from adjacent inhabited buildings by at least 10 meters.
11. Structural redundancy	Use highly redundant structural systems.
12. Internal circulation	Design building circulation to facilitate visual detection of unauthorized personnel approaching controlled or occupied areas.
13. Visitor control	Keep visitor access control locations away from sensitive or critical building areas and areas with large population densities.
14. Asset location	Locate critical assets and mission-critical personnel away from the building exterior.
15. Room layout	Position personnel and critical equipment to minimize exposure to direct blast effects.
16. External hallways	Avoid exterior hallway configurations for inhabited structures.
17. Windows	Minimize the size and number of windows.

Source: GAO summary of DOD information.

Appendix IV: DOD's Sustainable Design Goals

Sustainable design, or development, generally refers to efforts to design, construct, maintain, and remove facilities in ways that efficiently use energy, water, and materials; improve and protect environments; and provide long-term benefits for occupant health, productivity, and comfort. Sustainable design efforts are generally grouped under six fundamental principles—optimize site potential, optimize energy use, protect and conserve water, use environmentally preferable products and practices, enhance indoor environmental quality, and optimize operational and maintenance practices. Within the building industry, sustainable design is also known by such terms as green, high performance, or environmentally friendly.

DOD sustainable design requirements are contained in DOD's Unified Facilities Criteria 4-030-01, *Sustainable Development*. The document provides instruction, requirements, and references for DOD facility professionals and architect/engineer and construction contractors to apply sustainable development principles and strategies consistently in DOD facilities throughout their life cycle—from planning to programming and securing of funds; to site selection, design, and construction; to documentation and operations and maintenance; and to reuse or deconstruction and removal. The document's purpose is to help produce and maintain DOD facilities that comply with existing service policies and federal mandates for sustainable design, energy efficiency, and procurement of environmentally preferable materials. Further, the document provides guidance to help reduce the total cost of facility ownership, while minimizing negative impacts on the environment and promoting productivity, health, and comfort of building occupants.

To help measure the sustainability of new military buildings, DOD uses the U.S. Green Building Council's Leadership in Energy and Environmental Design Green Building Rating System. Created in 1998, the rating system represents the Council's effort to provide a nationally accepted benchmark for the design, construction, and operation of high-performance green buildings. The system also provides for a certification program for new construction projects by identifying a set of prerequisites and credits categorized under several environmental categories. The prerequisites are required tasks in order to be considered for a certification. The credits are tasks, steps, or measures that could be incorporated into a construction project and include a variable number of points—some based on performance levels and some based on addressing distinct measures related to an overarching sustainable concept. The United States Green Building Council can award a specific certification level to a new building depending on the total number of points achieved in the design and

construction of the building. The certification levels for new construction and renovation projects under the 2009 rating system include: certified (40 to 49 points), silver (50 to 59 points), gold (60 to 79 points), and platinum (80 points and above). For fiscal year 2009, DOD set a goal that at least 70 percent of DOD's new buildings would be silver-level certifiable. However, each of the military services set a goal that beginning in fiscal year 2009 all new major military construction buildings would be designed and constructed to be silver-level certifiable.

Table 6 below shows by category the prerequisites, credits, and available points under the U.S. Green Building Council's Leadership in Energy and Environmental Design Green Building Rating System.

Table 6: Rating System's Prerequisites, Credits, and Points for New Buildings

Category	Prerequisites and credits	Points
Sustainable sites	Prerequisite:	
(26 possible points)	Construction activity pollution prevention	
	Credits:	
	Site selection	1
	Development density and community connectivity	5
	Brownfield redevelopment	1
	Alternative transportation—public transportation access	6
	Alternative transportation—bicycle storage and changing rooms	1
	Alternative transportation—low-emitting and fuel-efficient vehicles	3
	Alternative transportation—parking capacity	2
	Site development—protect or restore habitat	1
	Site development—maximize open space	1
	Storm water design—quantity control	1
	Storm water design—quality control	1
	Heat island effect—nonroof	1
	Heat island effect—roof	1
	Light-pollution reduction	1
Water efficiency	Prerequisite:	
(10 possible points)	Water-use reduction	
	Credits:	
	Water-efficient landscaping	2 to 4
	Innovative wastewater technologies	2
	Water-use reduction	2 to 4

Category	Prerequisites and credits	Points
Energy and atmosphere	Prerequisites:	
(35 possible points)	Fundamental commissioning of building energy systems	
	Minimum energy performance	
	Fundamental refrigerant management	
	Credits:	
	Optimize energy performance	1 to 19
	On-site renewable energy	1 to 7
	Enhanced refrigerant management	2
	Enhanced commissioning	2
	Measurement and verification	3
	Green power	2
Materials and resources	Prerequisite:	
(14 possible points)	Storage and collection of recyclables	
	Credits:	
	Building reuse—maintain existing walls, floors and roof	1 to 3
	Building reuse—maintain existing interior nonstructural elements	1
	Construction waste management	1 to 2
	Materials reuse	1 to 2
	Recycled content	1 to 2
	Regional materials	1 to 2
	Rapidly renewable materials	1
	Certified wood	1
Indoor environmental quality	Prerequisites:	
(15 possible points)	Minimum indoor air quality performance	
	Environmental tobacco smoke control	
	Credits:	
	Outdoor air delivery monitoring	1
	Increased ventilation	1
	Construction indoor air quality management plan—during construction	1
	Construction indoor air quality management plan—before occupancy	1
	Low-emitting materials—adhesives and sealants	1
	Low-emitting materials—paints and coatings	1
	Low-emitting materials—flooring systems	1
	Low-emitting materials—composite wood and agricultural fiber products	1
	Indoor chemical and pollutant source control	1
	Controllability of systems—lighting	1
	Controllability of systems—thermal comfort	1

Category	Prerequisites and credits	Points
	Thermal comfort—design	1
	Thermal comfort—verification	1
	Daylight and views—daylight	1
	Daylight and views—views	1
Innovation in design	Credits:	
(6 possible points)	Innovation in design	1 to 5
	Leadership in Energy and Environmental Design accredited professional	1

Source: GAO summary of U.S. Green Building Council's Leadership in Energy and Environmental Design Green Building Rating System information.

Note: Also available are from 1 to 4 regional priority bonus points which acknowledge the importance of local conditions in determining best environmental design and construction practices.

Appendix V: GAO Contact and Staff Acknowledgments

GAO Contact

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Related GAO Products

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