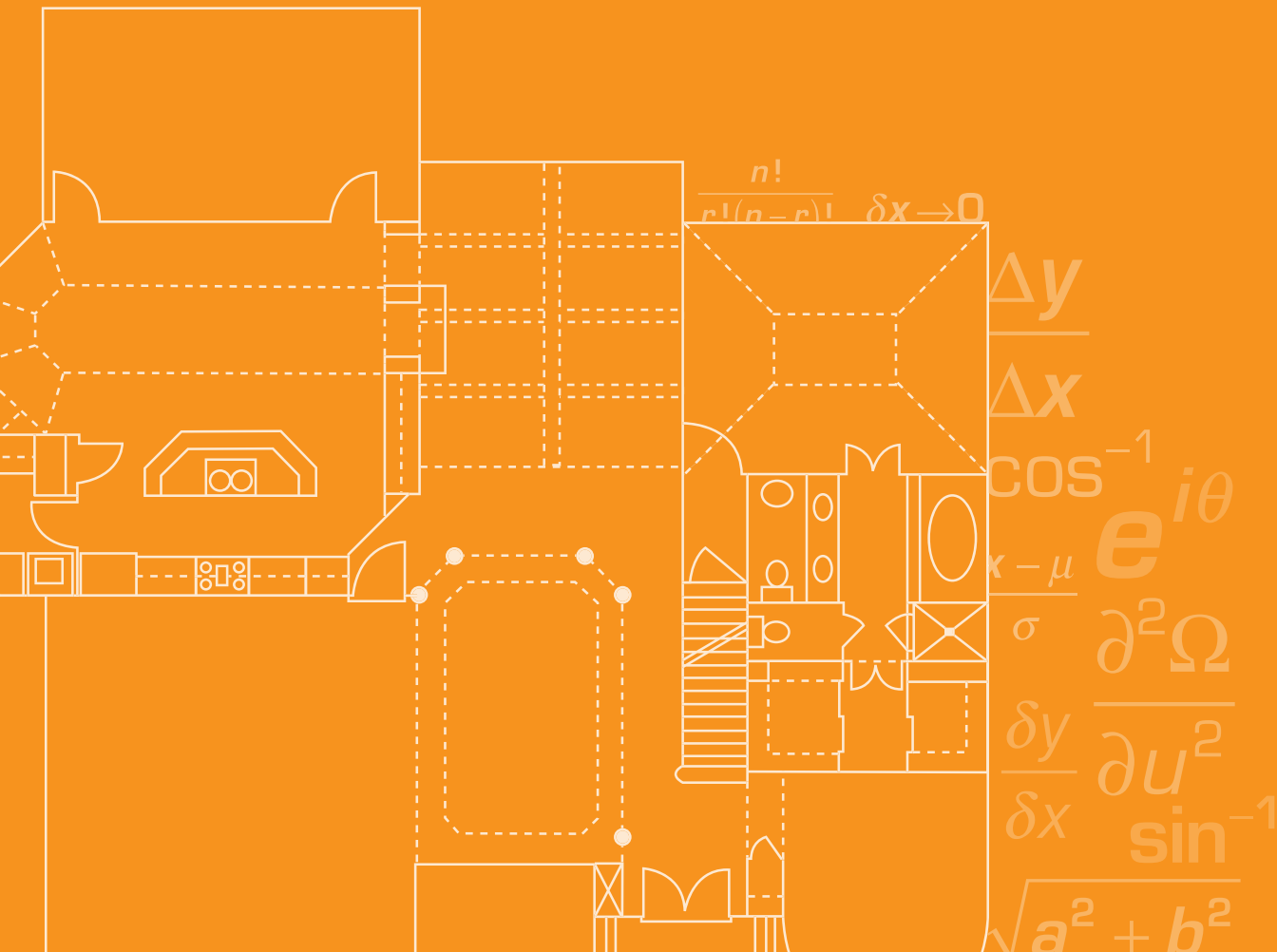
Achieve, Inc.

mathematics at work

Construction



Mathematics in the Construction Sector

The construction industry stands out as one of the largest and most vibrant industries in the country, employing about 8 million individuals. Everyone working in the critical field of construction, regardless of their particular area of expertise or specialty, will use mathematics on the job each and every day. From the simplest measurements to the most complicated fittings, algebra, geometry and trigonometry are necessary for workers in this industry to do their jobs successfully.

Available Construction Jobs

Within the construction industry, there are a variety of entry-level jobs that pay well and provide opportunities for advancement — jobs for high school graduates with postsecondary training or education but less than a four-year college degree. Construction is a field with true potential for upward mobility after sufficient on-the-job experience. With nearly 2 million self-employed — or family-employed — workers in construction, the construction industry offers many opportunities for workers to form their own firms and fulfill the American entrepreneurial dream.

Core Mathematics Knowledge in Today's Construction Jobs

Developed by secondary, postsecondary, business, industry and government leaders, the national Career Cluster Pathway Plans of Study for *Construction* and *Construction Maintenance and Operations* recommend a set of rigorous mathematics courses for students to take at both the secondary and postsecondary levels in traditional or vocational settings to pursue a career track in the construction sector. These Plans of Study show in detail how the foundation provided by courses such as Algebra I, Geometry, Algebra II, Trigonometry or Statistics, and Physics equips high school graduates with the mathematical knowledge and skills needed for success on the job. Until high school graduates understand the advanced mathematical skills used in the construction sector, they will remain unable to meet the demands of this high-growth industry. For more information on the Career Clusters Initiative, see www.careerclusters.org/resources/web/pos.cfm.

Jobs	Median yearly salary	Percentage of total jobs by education/training (ages 25–44)*		Number of total jobs		
		High school	Some college	2006	2016	% change
First-line supervisors/ managers of construction trades and extraction workers	$53,900	60%	30%	771,800	841,800	9%
Carpenters	$36,500	73%	22%	1,462,100	1,612,100	10%
Roofers	$32,300	86%	11%	156,300	178,700	14%

*Remaining percentage of workers in occupation have a bachelor's degree or higher

Source: Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Outlook Handbook, 2008–09 Edition.*

Ensuring College and Career Readiness: The American Diploma Project

In 2001, Achieve and several partner organizations launched the American Diploma Project (ADP) to identify a common core of English and mathematics academic knowledge and skills, sometimes referred to as "benchmarks," that American high school graduates need for success in college and the workforce. These ADP benchmarks, released in the 2004 report *Ready or Not? Creating a High School Diploma That Counts,* are the result of two years of intensive research conducted in colleges and universities as well as workplaces across the country.

The real-world expectations identified by ADP are significantly more rigorous than many current high school graduation standards — which helps explain why many high school graduates arrive at college or the workplace with major gaps in their English or mathematics preparation.

To help pinpoint the academic knowledge and skills required for future employment, ADP commissioned leading economists to examine labor market projections for the most promising occupations — those that pay enough to support a family and provide real potential for career advancement. ADP then surveyed officials from 22 industries, ranging from manufacturing to financial services, about the most useful skills for their employees to bring to the job.

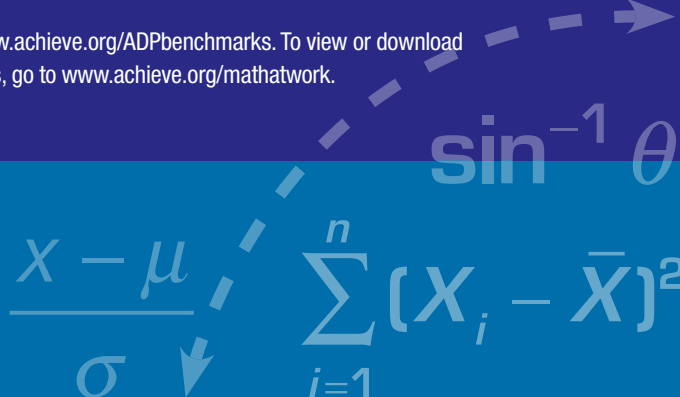
ADP also worked closely with two- and four-year postsecondary faculty from five partner states to determine the prerequisite English and mathematics knowledge and skills required to succeed in entry-level, credit-bearing higher education courses. These conversations revealed an unprecedented convergence of the knowledge and skills employers and postsecondary faculty say are needed for new employees and freshmen beginning credit-bearing coursework to be successful.

"Mathematics at Work" Series

Following up on the work of ADP, Achieve has produced a series of "Mathematics at Work" brochures to examine how higher-level mathematics is used in today's workplaces. The brochures present case studies drawn from leading industries nationwide to illustrate the advanced mathematics knowledge and skills embedded in jobs that offer opportunities for advancement and are accessible to high school graduates.

The series underscores the value of a rigorous high school curriculum in mathematics. All high school graduates — regardless of whether they enroll in college, join the workforce or enter the military — benefit from acquiring a comprehensive knowledge base and skill set in mathematics.

To view or download the ADP benchmarks, go to www.achieve.org/ADPbenchmarks. To view or download a PDF of additional "Mathematics at Work" brochures, go to www.achieve.org/mathatwork.



Mathematics builds

Career Preparation for the Construction Industry

The construction industry is filled with individuals with all sorts of backgrounds and training. The freedom of not being restricted by one specific degree or certification allows anybody with an interest in construction, an ability to work as part of a team and a keen understanding of mathematics to be successful in this field.

Many individuals learn the construction trade as part of a rigorous career and technical education (CTE) program starting in high school. In many communities, high schools and community colleges are joining together to develop integrated programs of study that allow students to master the classroom learning — in particular the advanced mathematics — critical to the construction industry while gaining hands-on experience through work-based learning. Students can earn a high school diploma while developing an understanding of the construction business from the inside. Some pathways include fully integrated courses that teach advanced mathematics content through construction projects such as building a house for Habitat for Humanity or remodeling a wing of a high school, as well as other rigorous academic and career-oriented courses.

Although there is no mandatory degree or certification that individuals need to enter the construction field, many employers place a premium on such distinctions. The National Center for Construction Education and Research (NCCER), an organization dedicated to addressing the industry shortage of contractors (persons who oversee all project aspects during the construction or development of a property), provides standardized construction and maintenance curricula — the Contren Learning Series — to high schools, community colleges and individuals. NCCER offers a certification assessment and portable credentials that signal an individual's career readiness. Assessment results are maintained in NCCER's National Registry, through which employers can find qualified employees.

NCCER's curricula run the full spectrum of building competencies, from carpentry and construction technology to other specializations including welding, site layout and even hydro-blasting. Present throughout the curricula's performance objectives are rigorous mathematical concepts and applications. For example:

- Carpentry (e.g., scale factor, isoclines/lines of constant elevation, angular measurement and conversions, calculations with decimals and fractions, converting distance and direction into latitudes and departures)
- Construction Technology (e.g., unit conversions, Pythagorean theorem, sampling methods, right-triangle trigonometry, volume of cylinders)
- Site Layout (e.g., angles and geometric figures; powers and square roots; unit conversions for lengths, areas and volumes; interpreting drawings)
- Project Supervision (e.g., bar graphs, network diagrams, rates of productivity)

More than 2,000 schools in the United States use NCCER's curricula, and about half of the states have built these curricula and assessments into their CTE construction pathways. Regardless of whether individuals receive credentials from NCCER, earn an associate degree in a relevant field or learn their trade on the job, they will need a solid foundation in mathematics to truly be prepared for a lifelong career in construction. For more information on NCCER, see www.nccer.org.

Construction Calculations: The Mathematics of Building Homes

Each month, more than a million permits are issued for the construction of new homes — and another million-plus privately owned residential construction projects are completed. Construction is a critical industry in our economy, and mathematically adept workers in this industry remain in high demand. The popular notion of a carpenter with a tape measure is far from the truth of today's sophisticated approach toward construction, which involves much more than simple measurements. Also, with close to 2 million self-employed or small-business contractors in this industry, contractors need both steady hands in construction and steady heads for business. From pouring the foundation to managing costly projects in an ever-changing industry, the success of contractors as both builders and entrepreneurs is tied to their ability to apply advanced mathematics.

Laying the Physical Foundation

Number Sense, Geometry and Trigonometry

In an ideal world, contractors would erect every home on level ground. As this is rarely the case, most home-building projects begin by reshaping the land. Calculating the slope of the ground starts a lengthy process of determining cut-and-fill areas so that the foundation rests on even ground. To minimize their costs, contractors and their teams need to site the foundation in ways that reduce the amount of material needed to create a level surface. Mathematically adept contractors and surveyors may even position a house precisely so that any removed soil can be "recycled" as fill elsewhere.

All experienced contractors know the importance of right angles and double-checking using the 3-4-5 rule. However, the fashionable curved walls and winding hallways of modern construction are built on customized, irregularly shaped foundation slabs that require builders to be familiar with calculating lengths and areas using advanced mathematical skills that depart from the traditional tape measure approach.

> *"Understanding mathematics is central to all aspects of running my business. I use mathematics every day on my work sites to make sure my houses are built strong and in my office so that my books are always balanced."*
>
> Keith Hayashi, Esq.
> *Herbert Chock & Associates, Inc.*
> *Construction/Engineering Consultants*

At this initial stage of home construction, contractors must work with structural engineers to determine the weight-bearing capacity of the foundation to prevent any structural hazards when the foundation later settles. It is critical while framing the foundation to determine the precise distribution and volume of concrete needed to ensure the building's structural integrity. Because reliable calculations at this stage of the process are essential for the foundation to be poured properly and the structure erected successfully, contractors must be able to both read sophisticated architectural plans coded in the language of mathematics and rely on their own construction teams' measurements (see box on next panel for an example).

Once the foundation has been laid, the work of a contractor has only just begun. Framing a house requires understanding every aspect of construction, and contractors must manage others and ensure that every calculation is exact. Installing a staircase requires calculating the rise and length of each stair with precision to ensure no missteps.

Building from the Bottom Up

The area of the concrete floor needed in this house is the area of the orange rectangle *plus* the extra parts of the library, grand room, garage, laundry/morning room and foyer. The areas of various rooms outside the orange rectangle that must be calculated are:

Library: $A_1 = (13' 9" - R)(11' 4") + \pi R^2/2 - (l_3 - l_7 - 14')(11' 4")$

Grand Room: $A_g = 15' \, l_5$

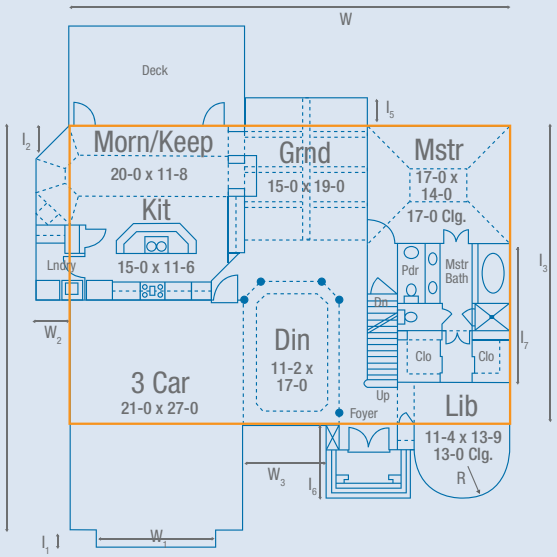
Garage: $A_c = (l - l_3)(21') + l_1 \, W_1$

Laundry/Morning Room: $A_m = (11' 6" + 11' 8") \, W_2 - l_2 \, W_2 / 2 = (23' 2" - l_2/2) \, W_2$

Foyer: $A_f = l_6 \, (W - 21' - W_3 - 11' 4")$

Therefore, the *area* of the concrete floor is:
$A = l_3 \, W + A_1 + A_g + A_c + A_m + A_f$.

The *volume* of concrete that needs to be ordered, in cubic feet, is equal to $V = A \, h$, where h is the thickness of the concrete block in feet.



Doors and windows must be hung plumb, level and square, or they will not close properly. Installing the right volume of insulation between the studs and the ceiling so that plumbers and electricians can run the correct lengths of pipes and wiring safely behind the drywall requires a whole host of mathematical calculations from everyone involved in the construction project. Even the final steps of completing a house — laying down the tiles in the kitchen and the hardwood floor in the living room — are dependent on knowing how to calculate irregularly shaped areas to leave behind the least amount of scrap and save costs.

Laying the Financial Foundation

Number Sense, Algebra and Forecasting

The best contractors are those who rigorously plan before they build. Evaluating potential costs for their project estimates is crucial for the financial well-being of their businesses. Contractors have to factor in the costs of labor, materials and equipment rentals to make hiring and purchasing decisions that maximize their return on time and energy. Contractors also must identify overhead costs (or additional indirect labor costs) and determine a gross margin percentage (or the "mark-up price") to charge their clients enough to make a profit, which can be further complicated by fluctuations in the cost of labor and materials and rates of inflation. When first starting up, expanding their business or financing a project, contractors need to understand the dynamics of interest rates and compound interest to get the best rate possible to meet their business needs and pay off their loans in a timely fashion. Lastly, contractors need to understand prevailing conditions in the housing market to judge whether a project is likely to turn a profit and weigh those profits against potential risks.

Mathematics + Teamwork = Success

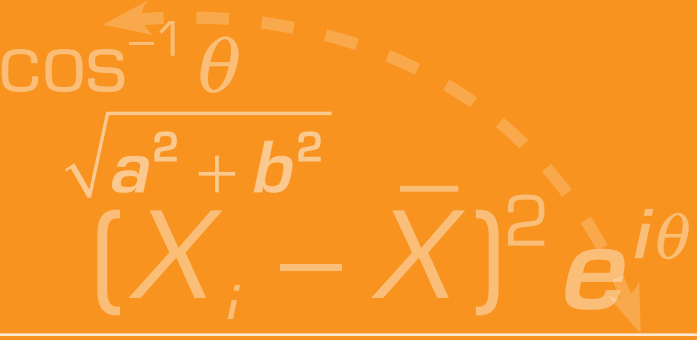
Although contractors rely on their knowledge of mathematics at every stage of the construction process, teamwork and communication skills play an equally important role in the success of construction projects of any size or type. From pouring the foundation to raising the roof, mathematics is integral to building a home or other property — and without the ability to communicate with and motivate a range of people, those calculations are not enough to convert blueprints into physical buildings. To be a successful small-business entrepreneur, today's contractor must be adept both at mathematics and team leadership.

The marriage of mathematics and teamwork is apparent throughout the construction process. Contractors have to work with equipment operators to clear and level the site, calculating precisely where to locate the structure and how much land to move. They need to read architectural plans coded in the language of mathematics and talk to structural engineers to ensure that the foundation is and will remain structurally sound. They must lead a construction crew in framing the house and ensure that every joint fits precisely and every door is hung level. They have to work with materials providers to purchase the right amount of shingles and bricks. They also need to be able to calculate true labor costs relative to the small-business loans needed to run their enterprise.

The fact that today's employers and employees need both mathematics and teamwork skills should not come as a surprise. Research shows that to be successful on a job site or in the college classroom, workers and students alike must be able to communicate, collaborate and apply mathematics. The most successful contractors can talk the language of entrepreneurs with their bank, speak to fellow small-business owners to purchase goods and services, and communicate with their subcontractors and employees on the job. Without core teamwork skills and a strong understanding of mathematics, contractors will be unable to be competitive in the growing construction industry.

The contractors of tomorrow must graduate from high school with the mathematical knowledge and teamwork skills that will allow them to succeed in the industry and offer them the opportunity to start their own businesses someday. The ADP college- and career-ready benchmarks provide the surest measure for today's students to graduate high school with the skills needed to build homes and construction businesses for the next generation.

> *"Everyone on a highway construction crew needs good math skills to correctly calculate quantities, measurements, supply orders. … Pretty much every aspect of construction involves some level of math skills."*
>
> James Thomas, Safety Director
> *Callanan Industries, Inc., Schenectady, New York*



About Achieve

Achieve, Inc., created by the nation's governors and business leaders, is a bipartisan, non-profit organization that helps states raise academic standards, improve assessments and strengthen accountability to prepare all young people for postsecondary education, careers and citizenship.

About the American Diploma Project (ADP) Network

In 2005, Achieve launched the ADP Network — a collaboration of states working together to improve their academic standards and provide all students with a high school education that meets the needs of today's workplaces and universities. The ADP Network members — responsible for educating 80 percent of all our nation's public high school students — are committed to taking four college and career readiness action steps:

1. Align high school standards with the demands of college and careers.
2. Require all students to complete a college- and career-ready curriculum to earn a high school diploma.
3. Build college- and career-ready measures into statewide high school assessment systems.
4. Hold high schools and postsecondary institutions accountable for student success.

The world has changed, and high schools must change with it. The ADP Network is leading the charge in ensuring that all high school students graduate with a degree that works.

Visit our Web site for more information about the ADP Network and the ADP benchmarks (www.achieve.org/ADPbenchmarks) and to view additional "Mathematics at Work" brochures (www.achieve.org/mathatwork).

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