Air Quality

- **Mapping Duct Layouts for Cleaner Airflow in Mobile Homes**
  Mapping Duct Layouts for Cleaner Airflow in Mobile Homes Inspecting Vent Connections for Improved Air Quality Minimizing Drafts Through Sealed Mobile Home Duct Systems Scheduling Regular Cleanings for Mobile Home Ventilation Evaluating Filter Efficiency for Enhanced Mobile Home Air Quality Addressing Mold Risks in Mobile Home Ductwork Installing Air Purification Systems in Mobile Homes Checking Air Pressure to Reduce Allergens in Mobile Home Interiors Identifying Common Leaks in Flexible Mobile Home Ducts Balancing Humidity Levels for Healthier Mobile Home Air Considering UV Technology for Mobile Home Air Treatment Using Diagnostic Tools to Assess Air Quality in Mobile Homes
- **Preparing Mobile Home HVAC Units for Intense Summer Heat**
  Preparing Mobile Home HVAC Units for Intense Summer Heat Protecting Mobile Home Furnaces During Low Temperature Periods Coping with Storm Related Damage to Mobile Home Air Conditioners Adjusting Climate Control in Mobile Homes for Coastal Humidity Handling Power Outages in Mobile Home Heating Systems Planning Winterization Steps for Mobile Home HVAC Equipment Adapting Mobile Homes to Rapid Seasonal Swings in Temperature Evaluating Wind Exposure Factors for Mobile Home AC Placement Addressing Extended Rainy Periods in Mobile Home Ventilation Considering Local Building Codes for Mobile Home Climate Adaptations Balancing Heat Needs in Mobile Homes Across Different Regions Checking Insurance Coverage for Storm Damaged Mobile Home AC Units
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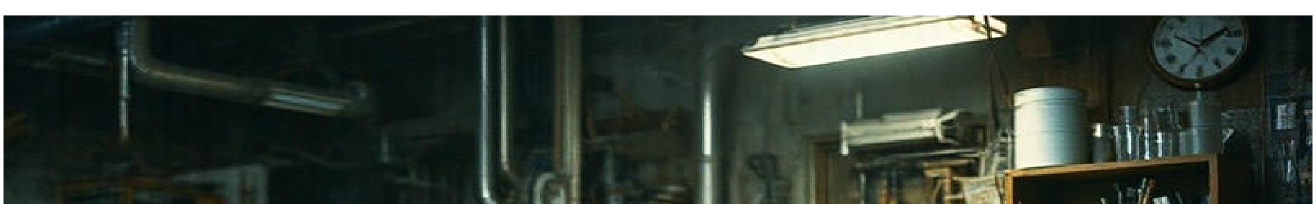

Considering UV Technology for Mobile Home Air Treatment

Importance of Efficient Duct Layouts for Airflow

The importance of air quality in mobile homes cannot be overstated. These compact living spaces offer unique challenges when it comes to maintaining a healthy indoor environment. With their limited space and often tighter construction, mobile homes can become breeding grounds for pollutants if not properly ventilated and maintained. This is where considering advanced solutions, such as UV technology for air treatment, becomes crucial.

Proper vent placement ensures even distribution of heated or cooled air **hvac for mobile home** building insulation.

Mobile homes are particularly susceptible to poor air quality due to several factors. The smaller square footage means that pollutants like dust, mold spores, chemicals from cleaning products, and allergens can accumulate more rapidly than in larger homes. Moreover, the construction materials often used in mobile homes may off-gas volatile organic compounds (VOCs), further compromising the indoor air quality. Given these challenges, ensuring fresh and clean air within a mobile home is essential for the health and well-being of its occupants.

One promising solution to address these issues is the implementation of ultraviolet (UV) technology in air treatment systems. UV technology has been widely recognized for its effectiveness in neutralizing airborne pathogens such as bacteria, viruses, and mold spores. It works by using ultraviolet light to disrupt the DNA of these microorganisms, rendering them harmless and preventing them from reproducing.

For mobile home residents concerned about respiratory health or allergies, incorporating UV technology into their existing HVAC systems or standalone air purifiers could provide significant benefits. By reducing the levels of harmful microorganisms in the air, individuals can experience fewer allergy symptoms and a lower risk of respiratory infections.

Another advantage of using UV technology is its ability to reduce odors caused by bacteria and molds that thrive in damp environments-a common issue in many mobile homes due to humidity control challenges. This results not only in healthier air but also in a more pleasant living environment overall.

Furthermore, UV technology requires minimal maintenance once installed correctly. Unlike filters that need regular replacement or cleaning, UV lamps generally need only periodic checks and occasional replacement every couple of years depending on usage-making it an efficient solution both economically and practically.

In conclusion, ensuring good air quality within a mobile home is essential given their unique vulnerabilities towards pollutant accumulation. Considering UV technology for improving indoor air offers an effective method for reducing airborne contaminants while also being relatively low-maintenance compared with other purification options available on the market today. Embracing this innovative approach will help create safer living conditions conducive towards better health outcomes for all those residing within these versatile yet challenging spaces we call home away from traditional housing structures!

In recent years, the integration of ultraviolet (UV) technology into HVAC systems has emerged as a promising method for enhancing indoor air quality. This advancement is particularly beneficial for mobile homes, where space and ventilation can be limited, making efficient air treatment crucial for maintaining a healthy living environment. Understanding how UV technology works within these systems can provide valuable insights for those considering its application in their mobile homes.

At its core, UV technology utilizes ultraviolet light to neutralize harmful microorganisms present in the air. These include bacteria, viruses, mold spores, and other pathogens that can circulate through HVAC systems and degrade indoor air quality. The implementation of UV lights within an HVAC system typically involves installing them near key components such as the evaporator coils or within the ductwork. This strategic placement ensures that as air circulates through the system, it is exposed to UV-C light-a specific wavelength known for its germicidal properties-effectively reducing microbial presence.

The operational principle behind this technology is relatively straightforward: when microorganisms are exposed to UV-C light, the radiation penetrates their cell walls and disrupts their DNA or RNA structure. This disruption impairs their ability to reproduce and ultimately leads to their destruction. By continuously sterilizing the air passing through the HVAC system, UV lights help maintain cleaner coils and ducts while preventing microbial buildup that could compromise system efficiency and air quality.

For mobile home residents contemplating this technology, there are several factors to consider. First is the potential improvement in health outcomes; by reducing airborne pathogens, occupants may experience fewer respiratory issues and allergic reactions. Additionally, maintaining cleaner coils can enhance HVAC efficiency, potentially leading to energy savings over time-a significant consideration given the compact nature of most mobile home systems.

However, it's essential to weigh these benefits against some practical considerations. Initial installation costs may be higher than traditional filtration methods, though many find this upfront investment worthwhile given the long-term benefits in terms of health and efficiency. Moreover, regular maintenance is necessary to ensure optimal performance; UV bulbs will need periodic replacement as their effectiveness diminishes over time.

In conclusion, incorporating UV technology into mobile home HVAC systems offers a compelling solution for those seeking improved indoor air quality and system efficiency. By understanding how it operates and evaluating both its advantages and considerations carefully, homeowners can make informed decisions about whether this innovative approach aligns with their needs and lifestyle preferences. As awareness grows around the importance of clean indoor environments, especially in compact living spaces like mobile homes, UV technology stands out as a viable option worthy of consideration.

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Techniques for Mapping Duct Layouts

In recent years, the quest for healthier indoor environments has become a significant concern, especially among mobile home residents. Mobile homes, with their compact spaces and unique ventilation challenges, often require innovative solutions to ensure air quality. One such solution gaining traction is the use of ultraviolet (UV) technology for air treatment. This essay explores the benefits of using UV technology in mobile homes and why it should be considered as a viable option for improving indoor air quality.

To begin with, UV technology offers an effective means of reducing airborne pathogens and allergens. Ultraviolet light can neutralize bacteria, viruses, and mold spores by disrupting their DNA structure, rendering them harmless. In the confined space of a mobile home, where traditional ventilation may not be as effective as in larger residences, this can significantly reduce the concentration of harmful microorganisms in the air. Consequently, this reduction leads to a decreased risk of respiratory illnesses and allergic reactions among occupants.

Moreover, UV technology contributes to odor control within mobile homes. Odors caused by cooking, pets, or other sources can linger longer in smaller spaces due to limited airflow. The application of UV light helps break down volatile organic compounds (VOCs) responsible for these odors. As a result, residents experience fresher and more pleasant indoor environments without relying on artificial air fresheners that might introduce additional chemicals into the air.

Energy efficiency is another compelling benefit of incorporating UV technology into mobile home air treatment systems. Unlike traditional HVAC systems that require significant energy consumption to filter and circulate air continuously, UV-based systems target contaminants directly without necessarily increasing energy usage. By improving overall system efficiency and potentially extending HVAC equipment lifespan through reduced microbial growth on coils and ducts, UV technology presents itself as an eco-friendly solution with long-term cost savings.

Furthermore, installing UV technology within a mobile home is relatively straightforward and requires minimal maintenance compared to other high-tech filtration methods. Many available units are designed for easy integration into existing HVAC systems or can operate independently as portable devices. Regular maintenance typically involves simple bulb replacements every 12-24 months depending on usage levels-an accessible task even for those without technical expertise.

Finally, adopting UV technology aligns with broader health trends emphasizing preventive measures over reactive treatments when it comes to wellness management at home settings-whether stationary or mobile living arrangements alike! This proactive approach ensures cleaner breathing spaces while simultaneously supporting sustainable living practices crucial amidst growing environmental concerns globally today!

In conclusion: Given its effectiveness against pathogens/allergens plus advantages like odor control/energy efficiency combined ease-of-installation/maintenance factors too-not forgetting alignment towards preventive health trends-it's clear why considering adopting ultraviolet solutions makes sense particularly if you're seeking healthier indoor atmospheres inside your beloved motorized abode!

Tools and Technologies for Accurate Duct Mapping

When thinking about ways to improve the air quality in mobile homes, ultraviolet (UV) technology often comes to mind as a viable solution. This technology, commonly used in hospitals and other institutional settings for its disinfection abilities, can also be applied in residential environments such as mobile homes. However, implementing UV technology is not as straightforward as plugging in an air purifier. There are several considerations that must be taken into account before making this investment.

First and foremost is the issue of space. Mobile homes typically offer limited living areas compared to traditional houses. Therefore, any UV system installed must be space-efficient and unobtrusive. Compact UV systems designed specifically for smaller spaces might be ideal; however, their effectiveness should not be compromised due to size constraints. Homeowners should ensure that the chosen system can adequately cover the entire area it is intended to purify.

Another critical consideration is cost-effectiveness. Mobile home owners often seek economical solutions due to budget constraints associated with their housing choice. While UV technology can provide excellent long-term benefits like reduced allergens and airborne pathogens, the initial installation costs can be high. It's important for homeowners to weigh these upfront expenses against potential health benefits and maintenance costs over time.

Furthermore, safety cannot be overlooked when implementing UV technology in confined spaces like mobile homes. Although UV-C light is effective at killing bacteria and viruses, direct exposure can be harmful to humans and pets. Systems need proper shielding or should be installed inside ductwork where no one will come into contact with the light directly.

Energy consumption also plays a significant role when considering UV installations. Mobile homes may have limited power supplies or may rely on alternative energy sources like solar panels, making energy-efficient models essential for sustainable use.

Lastly, maintenance requirements should factor into decision-making processes as well. Regular cleaning of bulbs or replacement parts may be necessary to keep the UV system operating effectively over time without decreasing performance levels due solely from lack of upkeep measures being taken seriously enough initially by users themselves who might otherwise neglect them until issues arise later down line unexpectedly causing more headaches than anticipated beforehand unfortunately leading toward potential dissatisfaction overall ultimately speaking too candidly perhaps but nonetheless honestly regarding this particular matter at hand today presently here now thus far stated clearly hopefully indeed yes indeed!

In conclusion then truly indeed without question it's clear beyond any reasonable doubt whatsoever certainly that while incorporating ultraviolet air treatment technologies does hold promise indeed especially within context specific applications such discussed earlier hereinabove mentioned prominently already prior thereto concerning aforementioned subject matter topics covered thoroughly albeit briefly succinctly yet comprehensively still nevertheless all things considered finally conclusively once again restated reaffirmed reiterated categorically emphatically undeniably unequivocally assuredly unquestionably satisfactorily successfully!

Best Practices for Cleaner Airflow

The integration of ultraviolet (UV) technology for air treatment in mobile homes represents a promising advancement in indoor air quality management. However, like any technological innovation, it comes with a set of potential challenges that must be addressed to ensure effective and safe implementation. Understanding these challenges and their possible solutions is crucial for homeowners and developers aiming to harness the benefits of UV air treatment.

One of the primary challenges is the initial cost of installing UV systems. Mobile homes, often chosen for their affordability, may not have the budgetary flexibility to accommodate this technology. UV systems can be expensive, both in terms of equipment and installation. To address this, manufacturers could explore more cost-effective production methods or provide financing options that spread out payments over time. Additionally, as demand grows and technology advances, economies of scale could naturally help reduce costs.

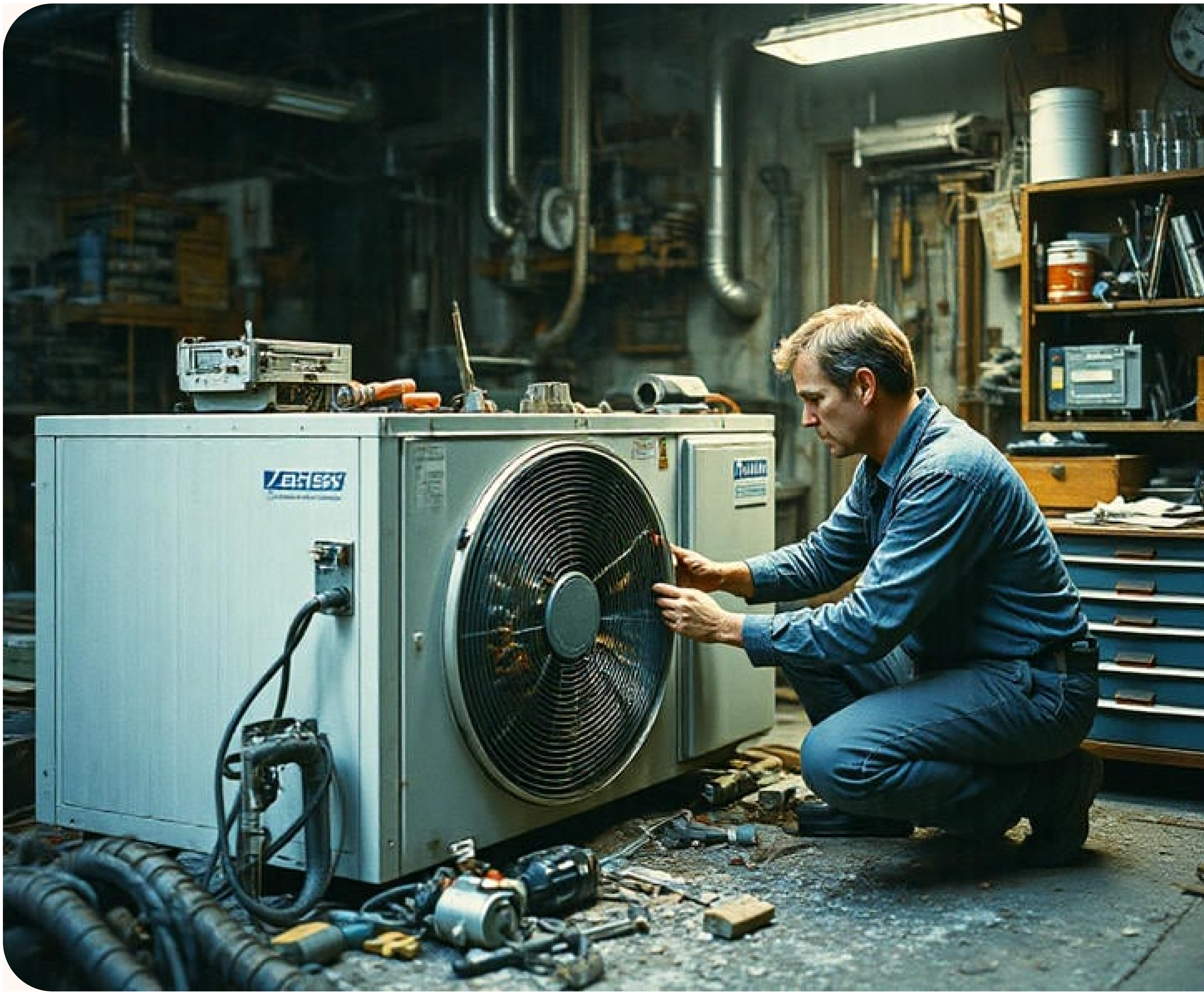
Another challenge lies in the proper maintenance and operation of UV systems. UV lamps require regular replacement to maintain effectiveness, as their ability to neutralize airborne pathogens diminishes over time. Homeowners may lack the technical knowledge needed to manage these systems efficiently. Educational initiatives and clear user manuals could empower users with the necessary skills for upkeep. Furthermore, creating partnerships with service providers who offer maintenance packages could alleviate this burden from homeowners.

Safety concerns also pose significant challenges when integrating UV technology into mobile homes. Exposure to UV-C light can be harmful to humans and pets if not properly contained within the system. To mitigate risks, robust safety features should be incorporated into all designs-such as automatic shutoff mechanisms when access panels are opened-and thorough testing should be conducted before market release.

In addition to these concerns, there is the challenge of ensuring compatibility with existing HVAC systems in mobile homes. These homes often have space constraints that might complicate retrofitting processes or limit options for installation locations. Collaborative efforts between HVAC manufacturers and UV technology developers could lead to compact designs that seamlessly integrate into current setups without compromising efficacy.

Lastly, consumer awareness is a pivotal factor influencing successful integration. Many people remain unaware of how UV technology works or its benefits beyond traditional filtration methods. Comprehensive marketing strategies paired with educational campaigns can increase public understanding and acceptance of UV air treatment solutions.

In conclusion, while there are notable challenges associated with integrating UV technology for mobile home air treatment-ranging from cost issues and maintenance needs to safety concerns-these obstacles are not insurmountable. Through innovative design approaches, strategic partnerships, educational efforts, and consumer engagement initiatives, it is possible to overcome these hurdles effectively. As we continue exploring sustainable ways to improve indoor air quality across various living environments-including mobile homes-embracing such advancements will play an essential role in fostering healthier living spaces for everyone involved.



Case Studies of Improved Air Quality in Mobile Homes

When considering the implementation of UV technology for air treatment in mobile homes, it's crucial to conduct a thorough cost analysis and evaluate energy efficiency. With increasing concerns about indoor air quality and the rising demand for sustainable solutions, UV systems present an intriguing option. However, understanding their economic feasibility and energy consumption is essential before making an investment.

Firstly, cost analysis begins with the initial purchase price of UV systems. These systems can vary widely in terms of complexity and capacity, influencing their upfront costs. For a standard mobile home, smaller units may suffice, which are generally less expensive than those designed for larger residential or commercial spaces. It's important to compare prices from different manufacturers while considering the reputation and reliability of each brand.

Beyond the initial purchase price, installation costs must also be factored into the overall budget. Depending on existing HVAC systems within the mobile home, additional components or modifications might be necessary to integrate UV technology effectively. Hiring professionals for installation ensures optimal placement and functioning but adds to the initial expenditure.

Maintenance costs represent another significant aspect of cost analysis. While UV lamps have a finite lifespan-typically around 9,000 to 12,000 hours-they require periodic replacement to maintain efficacy. The frequency of these replacements contributes to ongoing expenses that should not be overlooked when calculating long-term affordability.

Transitioning towards energy efficiency considerations, UV systems are relatively low-energy consumers compared to other air purification technologies. They operate using ultraviolet light to neutralize harmful pathogens without producing ozone or relying on chemical treatments. This approach not only ensures cleaner air but also minimizes environmental impact-a critical factor for those committed to eco-friendly living.

Nevertheless, it's crucial to assess the energy consumption specifics of any potential system thoroughly. More advanced models with added features like airflow sensors or variable speed controls could offer enhanced energy efficiency by adjusting operations based on real-time conditions within the mobile home.

Additionally, integrating smart technology can further optimize energy use by allowing homeowners to monitor and control their UV systems remotely. Such advancements enable users to tailor usage patterns according to occupancy levels or specific needs throughout different times of day-ultimately conserving more power.

In conclusion, investing in UV technology for mobile home air treatment requires careful consideration of both cost implications and energy efficiency benefits. Conducting a detailed analysis helps balance immediate financial outlays against long-term savings in maintenance and electricity bills while ensuring improved indoor air quality remains at its core value proposition. As consumers become increasingly conscious about health standards alongside environmental responsibilities; embracing innovative yet economically viable solutions like UV systems becomes ever more pertinent in today's world.

About Thermal comfort

This article is about comfort zones in building construction. For other uses, see Comfort zone (disambiguation).

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A thermal image of human

Thermal comfort is the condition of mind that expresses subjective satisfaction with the thermal environment.[1] The human body can be viewed as a heat engine where food is the input energy. The human body will release excess heat into the environment, so the body can continue to operate. The heat transfer is proportional to temperature difference. In cold environments, the body loses more heat to the environment and in hot environments the body does not release enough heat. Both the hot and cold scenarios lead to discomfort.[2] Maintaining this standard of thermal comfort for occupants of buildings or other enclosures is one of the important goals of HVAC (heating, ventilation, and air conditioning) design engineers.

Thermal neutrality is maintained when the heat generated by human metabolism is allowed to dissipate, thus maintaining thermal equilibrium with the surroundings. The main factors that influence thermal neutrality are those that determine heat gain and loss, namely metabolic rate, clothing insulation, air temperature, mean radiant temperature, air speed and relative humidity. Psychological parameters, such as individual expectations, and physiological parameters also affect thermal neutrality.[3] Neutral temperature is the temperature that can lead to thermal neutrality and it may vary greatly between individuals and depending on factors such as activity level, clothing, and humidity. People are highly sensitive to even small differences in environmental temperature. At 24 °C, a difference of 0.38 °C can be detected between the temperature of two rooms.[4]

The Predicted Mean Vote (PMV) model stands among the most recognized thermal comfort models. It was developed using principles of heat balance and experimental data collected in a controlled climate chamber under steady state conditions.[5] The adaptive model, on the other hand, was developed based on hundreds of field studies with the idea that occupants dynamically interact with their environment. Occupants control their thermal environment by means of clothing, operable windows, fans, personal heaters, and sun shades.[3][6] The PMV model can be applied to air-conditioned buildings, while the adaptive model can be applied only to buildings where no mechanical systems have been installed.[1] There is no consensus about which comfort model should be applied for buildings that are partially air-conditioned spatially or temporally.

Thermal comfort calculations in accordance with the ANSI/ASHRAE Standard 55,[1] the ISO 7730 Standard[7] and the EN 16798-1 Standard[8] can be freely performed with either the CBE Thermal Comfort Tool for ASHRAE 55,[9] with the Python package pythermalcomfort[10] or with the R package comf.

Significance

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Satisfaction with the thermal environment is important because thermal conditions are potentially life-threatening for humans if the core body temperature reaches conditions of hyperthermia, above 37.5–38.3 °C (99.5–100.9 °F),[11][12] or hypothermia, below 35.0 °C (95.0 °F).[13] Buildings modify the conditions of the external environment and reduce the effort that the human body needs to do in order to stay stable at a normal human body temperature, important for the correct functioning of human physiological processes.

The Roman writer Vitruvius actually linked this purpose to the birth of architecture.[14] David Linden also suggests that the reason why we associate tropical beaches with paradise is because in those environments is where human bodies need to do less metabolic effort to maintain their core temperature.[15] Temperature not only supports human life; coolness and warmth have also become in different cultures a symbol of protection, community and even the sacred.[16]

In building science studies, thermal comfort has been related to productivity and health. Office workers who are satisfied with their thermal environment are more productive.[17][18] The combination of high temperature and high relative humidity reduces thermal comfort and indoor air quality.[19]

Although a single static temperature can be comfortable, people are attracted by thermal changes, such as campfires and cool pools. Thermal pleasure is caused by varying thermal sensations from a state of unpleasantness to a state of pleasantness, and the scientific term for it is positive thermal alliesthesia.[20] From a state of thermal neutrality or comfort any change will be perceived as unpleasant.[21] This challenges the assumption that mechanically controlled buildings should deliver uniform temperatures and comfort, if it is at the cost of excluding thermal pleasure.[22]

Influencing factors

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Since there are large variations from person to person in terms of physiological and psychological satisfaction, it is hard to find an optimal temperature for everyone in a given space. Laboratory and field data have been collected to define conditions that will be found comfortable for a specified percentage of occupants.[1]

There are numerous factors that directly affect thermal comfort that can be grouped in two categories:

1. **Personal factors** – characteristics of the occupants such as metabolic rate and clothing level
2. **Environmental factors** – which are conditions of the thermal environment, specifically air temperature, mean radiant temperature, air speed and humidity

Even if all these factors may vary with time, standards usually refer to a steady state to study thermal comfort, just allowing limited temperature variations.

Personal factors

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Metabolic rate

[edit]
Main article: Metabolic rate

People have different metabolic rates that can fluctuate due to activity level and environmental conditions.[23][24][25] ASHRAE 55-2017 defines metabolic rate as the rate of transformation of chemical energy into heat and mechanical work by metabolic activities of an individual, per unit of skin surface area.[1]
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Metabolic rate is expressed in units of met, equal to 58.2 W/m² (18.4 Btu/h·ft²). One met is equal to the energy produced per unit surface area of an average person seated at rest.

ASHRAE 55 provides a table of metabolic rates for a variety of activities. Some common values are 0.7 met for sleeping, 1.0 met for a seated and quiet position, 1.2–1.4 met for light activities standing, 2.0 met or more for activities that involve movement, walking, lifting heavy loads or operating machinery. For intermittent activity, the standard states that it is permissible to use a time-weighted average metabolic rate if individuals are performing activities that vary over a period of one hour or less. For longer periods, different metabolic rates must be considered.[1]

According to ASHRAE Handbook of Fundamentals, estimating metabolic rates is complex, and for levels above 2 or 3 met – especially if there are various ways of performing such activities – the accuracy is low. Therefore, the standard is not applicable for activities with an average level higher than 2 met. Met values can also be determined more accurately than the tabulated ones, using an empirical equation that takes into account the rate of respiratory oxygen consumption and carbon dioxide production. Another physiological yet less accurate method is related to the heart rate, since there is a relationship between the latter and oxygen consumption.[26]

The Compendium of Physical Activities is used by physicians to record physical activities. It has a different definition of met that is the ratio of the metabolic rate of the activity in question to a resting metabolic rate.[27] As the formulation of the concept is different from the one that ASHRAE uses, these met values cannot be used directly in PMV calculations, but it opens up a new way of quantifying physical activities.

Food and drink habits may have an influence on metabolic rates, which indirectly influences thermal preferences. These effects may change depending on food and drink intake.[28]

Body shape is another factor that affects metabolic rate and hence thermal comfort. Heat dissipation depends on body surface area. The surface area of an average person is 1.8 m^2 (19 ft^2).[1] A tall and skinny person has a larger surface-to-volume ratio, can dissipate heat more easily, and can tolerate higher temperatures more than a person with a rounded body shape.[28]

Clothing insulation

[edit]
Main article: Clothing insulation

The amount of thermal insulation worn by a person has a substantial impact on thermal comfort, because it influences the heat loss and consequently the thermal balance. Layers of insulating clothing prevent heat loss and can either help keep a person warm or lead to overheating. Generally, the thicker the garment is, the greater insulating ability it has. Depending on the type of material the clothing is made out of, air movement and relative humidity can decrease the insulating ability of the material.[29][30]

1 clo is equal to 0.155 m^2·K/W (0.88 °F·ft^2·h/Btu). This corresponds to trousers, a long sleeved shirt, and a jacket. Clothing insulation values for other common ensembles or single garments can be found in ASHRAE 55.[1]

Skin wetness

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Skin wetness is defined as "the proportion of the total skin surface area of the body covered with sweat".[31] The wetness of skin in different areas also affects perceived thermal comfort. Humidity can increase wetness in different areas of the body, leading to a perception of discomfort. This is usually localized in different parts of the body, and local thermal comfort limits for skin wetness differ by locations of the body.[32] The extremities are much more sensitive to thermal discomfort from wetness than the trunk of the body. Although local thermal discomfort can be caused by wetness, the thermal comfort of the whole body will not be affected by the wetness of certain parts.

Environmental factors

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Air temperature

[edit]
Main article: Dry-bulb temperature

The air temperature is the average temperature of the air surrounding the occupant, with respect to location and time. According to ASHRAE 55 standard, the spatial average takes into account the ankle, waist and head levels, which vary for seated or standing occupants. The temporal average is based on three-minutes intervals with at least 18 equally spaced points in time. Air temperature is measured with a dry-bulb thermometer and for this reason it is also known as dry-bulb temperature.

Mean radiant temperature

[edit]
Main article: Mean radiant temperature

The radiant temperature is related to the amount of radiant heat transferred from a surface, and it depends on the material's ability to absorb or emit heat, or its emissivity. The mean radiant temperature depends on the temperatures and emissivities of the surrounding surfaces as well as the view factor, or the amount of the surface that is “seen” by the object. So the mean radiant temperature experienced by a person in a room with the sunlight streaming in varies based on how much of their body is in the sun.

Air speed

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Air speed is defined as the rate of air movement at a point, without regard to direction. According to ANSI/ASHRAE Standard 55, it is the average speed of the air surrounding a representative occupant, with respect to location and time. The spatial average is for three heights as defined for average air temperature. For an occupant moving in a space the sensors shall follow the movements of the occupant. The air speed is averaged over an interval not less than one and not greater than three minutes. Variations that occur over a period greater than three minutes shall be treated as multiple different air speeds.[33]

Relative humidity

[edit]
Main article: Relative humidity

Relative humidity (RH) is the ratio of the amount of water vapor in the air to the amount of water vapor that the air could hold at the specific temperature and pressure. While the human body has thermoreceptors in the skin that enable perception of temperature, relative humidity is detected indirectly. Sweating is an effective heat loss mechanism that relies on evaporation from the skin. However at high RH, the air has close to the maximum water vapor that it can hold, so evaporation, and therefore heat loss, is decreased. On the other hand, very dry environments (RH < 20–30%) are also uncomfortable because of their effect on the mucous membranes. The recommended level of indoor humidity is in the range of 30–60% in air conditioned buildings,[34][35] but new standards such as the adaptive model allow lower and higher humidity, depending on the other factors involved in thermal comfort.

Recently, the effects of low relative humidity and high air velocity were tested on humans after bathing. Researchers found that low relative humidity engendered thermal discomfort as well as the sensation of dryness and itching. It is recommended to keep relative humidity levels higher in a bathroom than other rooms in the house for optimal conditions.[36]

Various types of apparent temperature have been developed to combine air temperature and air humidity. For higher temperatures, there are quantitative scales, such as the heat index. For lower temperatures, a related interplay was identified only qualitatively:

- High humidity and low temperatures cause the air to feel chilly.[37]
- Cold air with high relative humidity "feels" colder than dry air of the same temperature because high humidity in cold weather increases the conduction of heat from the body.[38]

There has been controversy over why damp cold air feels colder than dry cold air. Some believe it is because when the humidity is high, our skin and clothing become moist and are better conductors of heat, so there is more cooling by conduction.[39]

The influence of humidity can be exacerbated with the combined use of fans (forced convection cooling).[40]

Natural ventilation

[edit]
Main article: Natural ventilation

Many buildings use an HVAC unit to control their thermal environment. Other buildings are naturally ventilated (or would have cross ventilation) and do not rely on mechanical systems to provide thermal comfort. Depending on the climate, this can drastically reduce energy consumption. It is sometimes seen as a risk, though, since indoor temperatures can be too extreme if the building is poorly designed. Properly designed, naturally ventilated buildings keep indoor conditions within the range where opening windows and using fans in the summer, and wearing extra clothing in the winter, can keep people thermally comfortable.[41]

Models and indices

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There are several different models or indices that can be used to assess thermal comfort conditions indoors as described below.

PMV/PPD method

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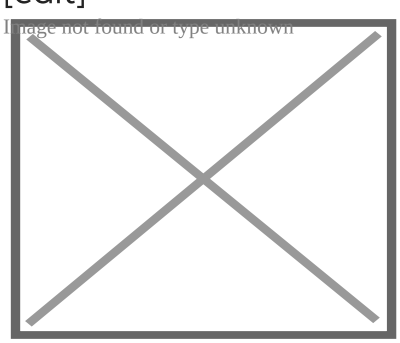
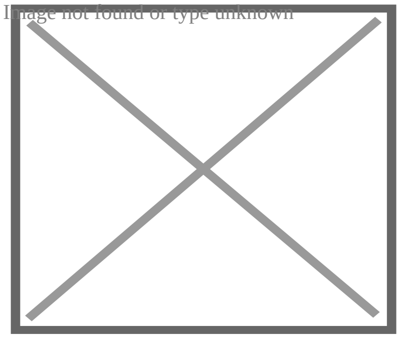


Psychrometric Chart



Temperature-relative humidity chart

Two alternative representations of thermal comfort for the PMV/PPD method

The PMV/PPD model was developed by P.O. Fanger using heat-balance equations and empirical studies about skin temperature to define comfort. Standard thermal comfort surveys ask subjects about their thermal sensation on a seven-point scale from cold (−3) to hot (+3). Fanger's equations are used to calculate the predicted mean vote (PMV) of a group of subjects for a particular combination of air temperature, mean radiant temperature, relative humidity, air speed, metabolic rate, and clothing insulation.[5] PMV equal to zero is representing thermal neutrality, and the comfort zone is defined by the combinations of the six parameters for which the PMV is within the recommended limits ($-0.5 < PMV < +0.5$).[1] Although predicting the thermal sensation of a population is an important step in determining what conditions are comfortable, it is more useful to consider whether or not people will be satisfied. Fanger developed another equation to relate the PMV to the Predicted Percentage of Dissatisfied (PPD). This relation was based on studies that surveyed subjects in a chamber where the indoor conditions could be precisely controlled.[5]

The PMV/PPD model is applied globally but does not directly take into account the adaptation mechanisms and outdoor thermal conditions.[3][42][43]

ASHRAE Standard 55-2017 uses the PMV model to set the requirements for indoor thermal conditions. It requires that at least 80% of the occupants be satisfied.[1]

The CBE Thermal Comfort Tool for ASHRAE 55[9] allows users to input the six comfort parameters to determine whether a certain combination complies with ASHRAE 55. The results are displayed on a psychrometric or a temperature-relative humidity chart and indicate the ranges of temperature and relative humidity that will be comfortable with the given the values input for the remaining four parameters.[44]

The PMV/PPD model has a low prediction accuracy.[45] Using the world largest thermal comfort field survey database,[46] the accuracy of PMV in predicting occupant's thermal sensation was only 34%, meaning that the thermal sensation is correctly predicted one out of three times. The PPD was overestimating subject's thermal unacceptability outside the thermal neutrality ranges (-1≤PMV≤1). The PMV/PPD accuracy varies strongly between ventilation strategies, building types and climates.[45]

Elevated air speed method

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ASHRAE 55 2013 accounts for air speeds above 0.2 metres per second (0.66 ft/s) separately than the baseline model. Because air movement can provide direct cooling to people, particularly if they are not wearing much clothing, higher temperatures can be more comfortable than the PMV model predicts. Air speeds up to 0.8 m/s (2.6 ft/s) are allowed without local control, and 1.2 m/s is possible with local control. This elevated air movement increases the maximum temperature for an office space in the summer to 30 °C from 27.5 °C (86.0–81.5 °F).[1]

Virtual Energy for Thermal Comfort

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"Virtual Energy for Thermal Comfort" is the amount of energy that will be required to make a non-air-conditioned building relatively as comfortable as one with air-conditioning. This is based on the assumption that the home will eventually install air-conditioning or heating.[47] Passive design improves thermal comfort in a building, thus reducing demand for heating or cooling. In many developing countries, however, most occupants do not currently heat or cool, due to economic constraints, as well as climate conditions which border lines comfort conditions such as cold winter nights in Johannesburg (South Africa) or warm summer days in San Jose, Costa Rica. At the same time, as incomes rise, there is a strong tendency to introduce cooling and heating systems. If we recognize and reward passive design features that improve thermal comfort today, we diminish the risk of having to install HVAC systems in the future, or we at least ensure that such systems will be smaller and less frequently used. Or in case the heating or cooling system is not installed due to high cost, at least people should not suffer from discomfort indoors. To provide an example, in San Jose, Costa Rica, if a house were being designed with high level of glazing and small opening sizes, the internal temperature would easily rise above 30 °C (86 °F) and natural ventilation would not be enough to remove the internal heat gains and solar gains. This is why Virtual Energy for Comfort is important.

World Bank's assessment tool the EDGE software (Excellence in Design for Greater Efficiencies) illustrates the potential issues with discomfort in buildings and has created the concept of Virtual Energy for Comfort which provides for a way to present potential thermal discomfort. This approach is used to award for design solutions which improves thermal comfort even in a fully free running building. Despite the inclusion of requirements for overheating in CIBSE, overcooling has not been assessed. However, overcooling can be an issue, mainly in the developing world, for example in cities such as Lima (Peru), Bogota, and Delhi, where cooler indoor temperatures can occur frequently. This may be a new area for research and design guidance for reduction of discomfort.

Cooling Effect

[edit]

ASHRAE 55-2017 defines the Cooling Effect (CE) at elevated air speed (above 0.2 metres per second (0.66 ft/s)) as the value that, when subtracted from both the air temperature and the mean radiant temperature, yields the same SET value under still air (0.1 m/s) as in the first SET calculation under elevated air speed.[1]

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$$\displaystyle SET(t_a,t_r,v,met,clo,RH)=SET(t_a-CE,t_r-CE,v=0.1,met,clo,RH)$$

The CE can be used to determine the PMV adjusted for an environment with elevated air speed using the adjusted temperature, the adjusted radiant temperature and still air (0.2 metres per second (0.66 ft/s)). Where the adjusted temperatures are equal to the original air and mean radiant temperatures minus the CE.

Local thermal discomfort

[edit]

Avoiding local thermal discomfort, whether caused by a vertical air temperature difference between the feet and the head, by an asymmetric radiant field, by local convective cooling (draft), or by contact with a hot or cold floor, is essential to providing acceptable thermal comfort. People are generally more sensitive to local discomfort when their thermal sensation is cooler than neutral, while they are less sensitive to it when their body is warmer than neutral.[33]

Radiant temperature asymmetry

[edit]

Large differences in the thermal radiation of the surfaces surrounding a person may cause local discomfort or reduce acceptance of the thermal conditions. ASHRAE Standard 55 sets limits on the allowable temperature differences between various surfaces. Because people are more sensitive to some asymmetries than others, for example that of a warm ceiling versus that of hot and cold vertical surfaces, the limits depend on which surfaces are involved. The ceiling is not allowed to be more than +5 °C (9.0 °F) warmer, whereas a wall may be up to +23 °C (41 °F) warmer than the other surfaces.[1]

Draft

[edit]

While air movement can be pleasant and provide comfort in some circumstances, it is sometimes unwanted and causes discomfort. This unwanted air movement is called "draft" and is most prevalent when the thermal sensation of the whole body is cool. People are most likely to feel a draft on uncovered body parts such as their head, neck, shoulders, ankles, feet, and legs, but the sensation also depends on the air speed, air temperature, activity, and clothing.[1]

Floor surface temperature

[edit]

Floors that are too warm or too cool may cause discomfort, depending on footwear. ASHRAE 55 recommends that floor temperatures stay in the range of 19–29 °C (66–84 °F) in spaces where occupants will be wearing lightweight shoes.[1]

Standard effective temperature

[edit]

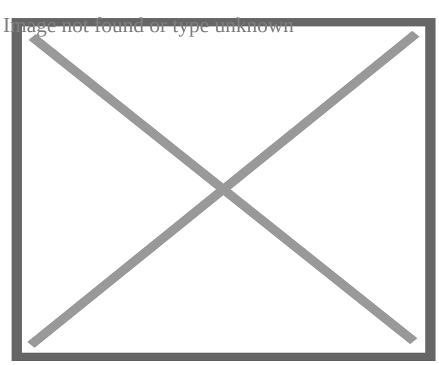
Standard effective temperature (SET) is a model of human response to the thermal environment. Developed by A.P. Gagge and accepted by ASHRAE in 1986,[48] it is also referred to as the Pierce Two-Node model.[49] Its calculation is similar to PMV because it is a comprehensive comfort index based on heat-balance equations that incorporates the personal factors of clothing and metabolic rate. Its fundamental difference is it takes a two-node method to represent human physiology in measuring skin temperature and skin wettedness.[48]

The SET index is defined as the equivalent dry bulb temperature of an isothermal environment at 50% relative humidity in which a subject, while wearing clothing standardized for activity concerned, would have the same heat stress (skin temperature) and thermoregulatory strain (skin wettedness) as in the actual test environment.[48]

Research has tested the model against experimental data and found it tends to overestimate skin temperature and underestimate skin wettedness.[49][50] Fountain and Huizenga (1997) developed a thermal sensation prediction tool that computes SET.[51] The SET index can also be calculated using either the CBE Thermal Comfort Tool for ASHRAE 55,[9] the Python package pythermalcomfort,[10] or the R package comf.

Adaptive comfort model

[edit]



Adaptive chart according to ASHRAE Standard 55-2010

The adaptive model is based on the idea that outdoor climate might be used as a proxy of indoor comfort because of a statistically significant correlation between them. The adaptive hypothesis predicts that contextual factors, such as having access to environmental controls, and past thermal history can influence building occupants' thermal expectations and preferences.[3] Numerous researchers have conducted field studies worldwide in which they survey building occupants about their thermal comfort while taking simultaneous environmental measurements. Analyzing a database of results from 160 of these buildings revealed that occupants of naturally ventilated buildings accept and even prefer a wider range of temperatures than their counterparts in sealed, air-conditioned buildings because their preferred temperature depends on outdoor conditions.[3] These results were incorporated in the ASHRAE 55-2004 standard as the adaptive comfort model. The adaptive chart relates indoor comfort temperature to prevailing outdoor temperature and defines zones of 80% and 90% satisfaction.[1]

The ASHRAE-55 2010 Standard introduced the prevailing mean outdoor temperature as the input variable for the adaptive model. It is based on the arithmetic average of the mean daily outdoor temperatures over no fewer than 7 and no more than 30 sequential days prior to the day in question.[1] It can also be calculated by weighting the temperatures with different coefficients, assigning increasing importance to the most recent temperatures. In case this weighting is used, there is no need to respect the upper limit for the subsequent days. In order to apply the adaptive model, there should be no mechanical cooling system for the space, occupants should be engaged in sedentary activities with metabolic rates of 1–1.3 met, and a prevailing mean temperature of 10–33.5 °C (50.0–92.3 °F).[1]

This model applies especially to occupant-controlled, natural-conditioned spaces, where the outdoor climate can actually affect the indoor conditions and so the comfort zone. In fact, studies by de Dear and Brager showed that occupants in naturally ventilated buildings were tolerant of a wider range of temperatures.[3] This is due to both behavioral and physiological adjustments, since there are different types of adaptive processes.[52] ASHRAE Standard 55-2010 states that differences in recent thermal experiences, changes in clothing, availability of control options, and shifts in occupant expectations can change people's thermal responses.[1]

Adaptive models of thermal comfort are implemented in other standards, such as European EN 15251 and ISO 7730 standard. While the exact derivation methods and results are slightly different from the ASHRAE 55 adaptive standard, they are substantially the same. A larger difference is in applicability. The ASHRAE adaptive standard only applies to buildings without mechanical cooling installed, while EN15251 can be applied to mixed-mode buildings, provided the system is not running.[53]

There are basically three categories of thermal adaptation, namely: behavioral, physiological, and psychological.

Psychological adaptation

[edit]

An individual's comfort level in a given environment may change and adapt over time due to psychological factors. Subjective perception of thermal comfort may be influenced by the memory of previous experiences. Habituation takes place when repeated exposure moderates future expectations, and responses to sensory input. This is an important factor in explaining the difference between field observations and PMV predictions (based on the static model) in naturally ventilated buildings. In these buildings, the relationship with the outdoor temperatures has been twice as strong as predicted.[3]

Psychological adaptation is subtly different in the static and adaptive models. Laboratory tests of the static model can identify and quantify non-heat transfer (psychological) factors that affect reported comfort. The adaptive model is limited to reporting differences (called psychological) between modeled and reported comfort.[*citation needed*]

Thermal comfort as a "condition of mind" is *defined* in psychological terms. Among the factors that affect the condition of mind (in the laboratory) are a sense of control over the temperature, knowledge of the temperature and the appearance of the (test) environment. A thermal test chamber that appeared residential "felt" warmer than one which looked like the inside of a refrigerator.[54]

Physiological adaptation

[edit]
Further information: Thermoregulation

The body has several thermal adjustment mechanisms to survive in drastic temperature environments. In a cold environment the body utilizes vasoconstriction; which reduces blood flow to the skin, skin temperature and heat dissipation. In a warm environment, vasodilation will increase blood flow to the skin, heat transport, and skin temperature and heat dissipation.[55] If there is an imbalance despite the vasomotor adjustments listed above, in a warm environment sweat production will start and provide evaporative cooling. If this is insufficient, hyperthermia will set in, body temperature may reach 40 °C (104 °F), and heat stroke may occur. In a cold environment, shivering will start, involuntarily forcing the muscles to work and increasing the heat production by up to a factor of 10. If equilibrium is not restored, hypothermia can set in, which can be fatal.[55] Long-term adjustments to extreme temperatures, of a few days to six months, may result in cardiovascular and endocrine adjustments. A hot climate may create increased blood volume, improving the effectiveness of vasodilation, enhanced performance of the sweat mechanism, and the readjustment of thermal preferences. In cold or underheated conditions, vasoconstriction can become permanent, resulting in decreased blood volume and increased body metabolic rate.[55]

Behavioral adaptation

[edit]

In naturally ventilated buildings, occupants take numerous actions to keep themselves comfortable when the indoor conditions drift towards discomfort. Operating windows and fans, adjusting blinds/shades, changing clothing, and consuming food and drinks are some of the common adaptive strategies. Among these, adjusting windows is the most common.[56] Those occupants who take these sorts of actions tend to feel cooler at warmer temperatures than those who do not.[57]

The behavioral actions significantly influence energy simulation inputs, and researchers are developing behavior models to improve the accuracy of simulation results. For example, there are many window-opening models that have been developed to date, but there is no consensus over the factors that trigger window opening.[56]

People might adapt to seasonal heat by becoming more nocturnal, doing physical activity and even conducting business at night.

Specificity and sensitivity

[edit]

Individual differences

[edit]
Further information: Cold sensitivity

The thermal sensitivity of an individual is quantified by the descriptor *FS*, which takes on higher values for individuals with lower tolerance to non-ideal thermal conditions.[58] This group includes pregnant women, the disabled, as well as individuals whose age is below fourteen or above sixty, which is considered the adult range. Existing literature provides consistent evidence that sensitivity to hot and cold surfaces usually declines with age. There is also some evidence of a gradual reduction in the effectiveness of the body in thermo-regulation after the age of sixty.[58] This is mainly due to a more sluggish response of the counteraction mechanisms in lower parts of the body that are used to maintain the core temperature of the body at ideal values.[58] Seniors prefer warmer temperatures than young adults (76 vs 72 degrees F or 24.4 vs 22.2 Celsius).[54]

Situational factors include the health, psychological, sociological, and vocational activities of the persons.

Biological sex differences

[edit]

While thermal comfort preferences between sexes seem to be small, there are some average differences. Studies have found males on average report discomfort due to rises in temperature much earlier than females. Males on average also estimate higher levels of their sensation of discomfort than females. One recent study tested males and females in the same cotton clothing, performing mental jobs while using a dial vote to report their thermal comfort to the changing temperature.[59] Many times, females preferred higher temperatures than males. But while females tend to be more sensitive to temperatures, males tend to be more sensitive to relative-humidity levels.[60][61]

An extensive field study was carried out in naturally ventilated residential buildings in Kota Kinabalu, Sabah, Malaysia. This investigation explored the sexes thermal sensitivity to the indoor environment in non-air-conditioned residential buildings. Multiple hierarchical regression for categorical moderator was selected for data analysis; the result showed that as a group females were slightly more sensitive than males to the indoor air temperatures, whereas, under thermal neutrality, it was found that males and females have similar thermal sensation.[62]

Regional differences

[edit]

In different areas of the world, thermal comfort needs may vary based on climate. In China[*where?*] the climate has hot humid summers and cold winters, causing a need for efficient thermal comfort. Energy conservation in relation to thermal comfort has become a large issue in China in the last several decades due to rapid economic and population growth.[63] Researchers are now looking into ways to heat and cool buildings in China for lower costs and also with less harm to the environment.

In tropical areas of Brazil, urbanization is creating urban heat islands (UHI). These are urban areas that have risen over the thermal comfort limits due to a large influx of people and only drop within the comfortable range during the rainy season.[64] Urban heat islands can occur over any urban city or built-up area with the correct conditions.[65][66]

In the hot, humid region of Saudi Arabia, the issue of thermal comfort has been important in mosques, because they are very large open buildings that are used only intermittently (very busy for the noon prayer on Fridays) it is hard to ventilate them properly. The large size requires a large amount of ventilation, which requires a lot of energy since the buildings are used only for short periods of time. Temperature regulation in mosques is a challenge due to the intermittent demand, leading to many mosques being either too hot or too cold. The stack effect also comes into play due to their large size and creates a large layer of hot air above the people in the mosque. New designs have placed the ventilation systems lower in the buildings to provide more temperature control at ground level.[67] New monitoring steps are also being taken to improve efficiency.[68]

Thermal stress

[edit]
Not to be confused with thermal stress on objects, which describes the change materials experience when subject to extreme temperatures.

The concept of thermal comfort is closely related to thermal stress. This attempts to predict the impact of solar radiation, air movement, and humidity for military personnel undergoing training exercises or athletes during competitive events.

Several thermal stress indices have been proposed, such as the Predicted Heat Strain (PHS) or the humidex.[69] Generally, humans do not perform well under thermal stress. People's performances under thermal stress is about 11% lower than their performance at normal thermal wet conditions. Also, human performance in relation to thermal stress varies greatly by the type of task which the individual is completing. Some of the physiological effects of thermal heat stress include increased blood flow to the skin, sweating, and increased ventilation.[70][71]

Predicted Heat Strain (PHS)

[edit]

The PHS model, developed by the International Organization for Standardization (ISO) committee, allows the analytical evaluation of the thermal stress experienced by a working subject in a hot environment.[72] It describes a method for predicting the sweat rate and the internal core temperature that the human body will develop in response to the working conditions. The PHS is calculated as a function of several physical parameters, consequently it makes it possible to determine which parameter or group of parameters should be modified, and to what extent, in order to reduce the risk of physiological strains. The PHS model does not predict the physiological response of an individual subject, but only considers standard subjects in good health and fit for the work they perform. The PHS can be determined using either the Python package pythermalcomfort[10] or the R package comf.

American Conference on Governmental Industrial Hygienists (ACGIH) Action Limits and Threshold Limit Values

[edit]

ACGIH has established Action Limits and Threshold Limit Values for heat stress based upon the estimated metabolic rate of a worker and the environmental conditions the worker is subjected to.

This methodology has been adopted by the Occupational Safety and Health Administration (OSHA) as an effective method of assesing heat stress within workplaces.[73]

Research

[edit]

The factors affecting thermal comfort were explored experimentally in the 1970s. Many of these studies led to the development and refinement of ASHRAE Standard 55 and were performed at Kansas State University by Ole Fanger and others. Perceived comfort was found to be a complex interaction of these variables. It was found that the majority of individuals would be satisfied by an ideal set of values. As the range of values deviated progressively from the ideal, fewer and fewer people were satisfied. This observation could be expressed statistically as the percent of individuals who expressed satisfaction by *comfort conditions* and the *predicted mean vote* (PMV). This approach was challenged by the adaptive comfort model, developed from the ASHRAE 884 project, which revealed that occupants were comfortable in a broader range of temperatures.[3]

This research is applied to create Building Energy Simulation (BES) programs for residential buildings. Residential buildings in particular can vary much more in thermal comfort than public and commercial buildings. This is due to their smaller size, the variations in clothing worn, and different uses of each room. The main rooms of concern are bathrooms and bedrooms. Bathrooms need to be at a temperature comfortable for a human with or without clothing. Bedrooms are of importance because they need to accommodate different levels of clothing and also different metabolic rates of people asleep or awake.[74] Discomfort hours is a common metric used to evaluate the thermal performance of a space.

Thermal comfort research in clothing is currently being done by the military. New air-ventilated garments are being researched to improve evaporative cooling in military settings. Some models are being created and tested based on the amount of cooling they provide.[75]

In the last twenty years, researchers have also developed advanced thermal comfort models that divide the human body into many segments, and predict local thermal discomfort by considering heat balance.[76][77][78] This has opened up a new arena of thermal comfort modeling that aims at heating/cooling selected body parts.

Another area of study is the hue-heat hypothesis that states that an environment with warm colors (red, orange yellow hues) will feel warmer in terms of temperature and comfort, while an environment with cold colors (blue, green hues) will feel cooler.[79][80][81] The hue-heat hypothesis has both been investigated scientifically [82] and ingrained in popular culture in the terms warm and cold colors [83]

Medical environments

[edit]

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Whenever the studies referenced tried to discuss the thermal conditions for different groups of occupants in one room, the studies ended up simply presenting comparisons of thermal comfort satisfaction based on the subjective studies. No study tried to reconcile the different thermal comfort requirements of different types of occupants who compulsorily must stay in one room. Therefore, it looks to be necessary to investigate the different thermal conditions required by different groups of occupants in hospitals to reconcile their different requirements in this concept. To reconcile the differences in the required thermal comfort conditions it is recommended to test the possibility of using different ranges of local radiant temperature in one room via a suitable mechanical system.

Although different researches are undertaken on thermal comfort for patients in hospitals, it is also necessary to study the effects of thermal comfort conditions on the quality and the quantity of healing for patients in hospitals. There are also original researches that show the link between thermal comfort for staff and their levels of productivity, but no studies have been produced individually in hospitals in this field. Therefore, research for coverage and methods individually for this subject is recommended. Also research in terms of cooling and heating delivery systems for patients with low levels of immune-system protection (such as HIV patients, burned patients, etc.) are recommended. There are important areas, which still need to be focused on including thermal comfort for staff and its relation with their productivity, using different heating systems to prevent hypothermia in the patient and to improve the thermal comfort for hospital staff simultaneously.

Finally, the interaction between people, systems and architectural design in hospitals is a field in which require further work needed to improve the knowledge of how to design buildings and systems to reconcile many conflicting factors for the people occupying these buildings.[84]

Personal comfort systems

[edit]

Personal comfort systems (PCS) refer to devices or systems which heat or cool a building occupant personally.[85] This concept is best appreciated in contrast to central HVAC systems which have uniform temperature settings for extensive areas. Personal comfort systems include fans and air diffusers of various kinds (e.g. desk fans, nozzles and slot diffusers, overhead fans, high-volume low-speed fans etc.) and personalized sources of radiant or conductive heat (footwarmers, legwarmers, hot water bottles etc.). PCS has the potential to satisfy individual comfort requirements much better than current HVAC systems, as interpersonal differences in thermal sensation due to age, sex, body mass, metabolic rate, clothing and thermal adaptation can amount to an equivalent temperature variation of 2–5 °C (3,6–9 °F), which is impossible for a central, uniform HVAC system to cater to.[85] Besides, research has shown that the perceived ability to control one's thermal environment tends to widen one's range of tolerable temperatures.[3] Traditionally, PCS devices have been used in isolation from one another. However, it has been proposed by Andersen et al. (2016) that a network of PCS devices which generate well-connected microzones of thermal comfort, and report real-time occupant information and respond to programmatic actuation requests (e.g. a party, a conference, a concert etc.) can combine with occupant-aware building applications to enable new methods of comfort maximization.[86]

See also

[edit]

- ASHRAE
- ANSI/ASHRAE Standard 55
- Air conditioning
- Building insulation
- Cold and heat adaptations in humans
- Heat stress
- Mean radiant temperature
- Mahoney tables
- Povl Ole Fanger
- Psychrometrics
- Ralph G. Nevins
- Room air distribution
- Room temperature
- Ventilative cooling

References

[edit]

1. ^ ***a b c d e f g h i j k l m n o p q r s*** ANSI/ASHRAE Standard 55-2017, Thermal Environmental Conditions for Human Occupancy
2. **^** *Çengel, Yunus A.; Boles, Michael A. (2015). Thermodynamics: An Engineering Approach (8th ed.). New York, NY: McGraw-Hill Education. ISBN 978-0-07-339817-4.*

3. ^ ***a b c d e f g h i*** *de Dear, Richard; Brager, Gail (1998). "Developing an adaptive model of thermal comfort and preference". ASHRAE Transactions.* ***104*** *(1): 145–67.*
4. **^** *Battistel, Laura; Vilardi, Andrea; Zampini, Massimiliano; Parin, Riccardo (2023). "An investigation on humans' sensitivity to environmental temperature". Scientific Reports.* ***13*** *(1). doi:10.1038/s41598-023-47880-5. ISSN 2045-2322. PMC 10695924. PMID 38049468.*
5. ^ ***a b c*** *Fanger, P Ole (1970). Thermal Comfort: Analysis and applications in environmental engineering. Danish Technical Press. ISBN 8757103410.*[*page needed*]
6. **^** *Nicol, Fergus; Humphreys, Michael (2002). "Adaptive thermal comfort and sustainable thermal standards for buildings" (PDF). Energy and Buildings.* ***34*** *(6): 563–572. doi:10.1016/S0378-7788(02)00006-3. S2CID 17571584.*[*permanent dead link*]
7. **^** ISO, 2005. ISO 7730 – Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria.
8. **^** CEN, 2019. EN 16798-1 – Energy performance of buildings – Ventilation for buildings. Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics.
9. ^ ***a b c*** *Tartarini, Federico; Schiavon, Stefano; Cheung, Toby; Hoyt, Tyler (2020). "CBE Thermal Comfort Tool: Online tool for thermal comfort calculations and visualizations". SoftwareX.* ***12****: 100563. Bibcode:2020SoftX..1200563T. doi:10.1016/j.softx.2020.100563. S2CID 225631918.*
10. ^ ***a b c*** *Tartarini, Federico; Schiavon, Stefano (2020-07-01). "pythermalcomfort: A Python package for thermal comfort research". SoftwareX.* ***12****: 100578. Bibcode:2020SoftX..1200578T. doi:10.1016/j.softx.2020.100578. ISSN 2352-7110. S2CID 225618628.*
11. **^** *Axelrod, Yekaterina K.; Diringer, Michael N. (2008). "Temperature Management in Acute Neurologic Disorders". Neurologic Clinics.* ***26*** *(2): 585–603. doi:10.1016/j.ncl.2008.02.005. ISSN 0733-8619. PMID 18514828.*
12. **^** *Laupland, Kevin B. (2009). "Fever in the critically ill medical patient". Critical Care Medicine.* ***37*** *(Supplement): S273–S278. doi:10.1097/ccm.0b013e3181aa6117. ISSN 0090-3493. PMID 19535958. S2CID 21002774.*
13. **^** *Brown, Douglas J.A.; Brugger, Hermann; Boyd, Jeff; Paal, Peter (2012-11-15). "Accidental Hypothermia". New England Journal of Medicine.* ***367*** *(20): 1930–1938. doi:10.1056/nejmra1114208. ISSN 0028-4793. PMID 23150960. S2CID 205116341.*

14. ^ *Vitruvius, Marcus (2001). The Ten Books of Architecture. Cambridge University Press. ISBN 978-1-107-71733-6.*
15. ^ *Linden, David J. (1961). Touch: the science of hand, heart, and mind. New York. ISBN 9780670014873. OCLC 881888093.*cite book: CS1 maint: location missing publisher (link)
16. ^ *Lisa., Heschong (1979). Thermal delight in architecture. Cambridge, Mass.: MIT Press. ISBN 978-0262081016. OCLC 5353303.*
17. ^ Wargocki, Pawel, and Olli A. Seppänen, et al. (2006) "Indoor Climate and Productivity in Offices". Vol. 6. *REHVA Guidebooks 6*. Brussels, Belgium: REHVA, Federation of European Heating and Air-conditioning Associations.
18. ^ *Wyon, D.P.; Andersen, I.; Lundqvist, G.R. (1981), "Effects of Moderate Heat Stress on Mental Performance", Studies in Environmental Science, vol. 5, no. 4, Elsevier, pp. 251–267, doi:10.1016/s0166-1116(08)71093-8, ISBN 9780444997616, PMID 538426*
19. ^ *Fang, L; Wyon, DP; Clausen, G; Fanger, PO (2004). "Impact of indoor air temperature and humidity in an office on perceived air quality, SBS symptoms and performance". Indoor Air. **14** (Suppl 7): 74–81. doi:10.1111/j.1600-0668.2004.00276.x. PMID 15330775.*
20. ^ *Cabanac, Michel (1971). "Physiological role of pleasure". Science. **173** (4002): 1103–7. Bibcode:1971Sci...173.1103C. doi:10.1126/science.173.4002.1103. PMID 5098954. S2CID 38234571.*
21. ^ *Parkinson, Thomas; de Dear, Richard (2014-12-15). "Thermal pleasure in built environments: physiology of alliesthesia". Building Research & Information. **43** (3): 288–301. doi:10.1080/09613218.2015.989662. ISSN 0961-3218. S2CID 109419103.*
22. ^ *Hitchings, Russell; Shu Jun Lee (2008). "Air Conditioning and the Material Culture of Routine Human Encasement". Journal of Material Culture. **13** (3): 251–265. doi:10.1177/1359183508095495. ISSN 1359-1835. S2CID 144084245.*
23. ^ *Toftum, J. (2005). "Thermal Comfort Indices". Handbook of Human Factors and Ergonomics Methods. Boca Raton, FL, USA: 63.CRC Press.*[*page needed*]
24. ^ *Smolander, J. (2002). "Effect of Cold Exposure on Older Humans". International Journal of Sports Medicine. **23** (2): 86–92. doi:10.1055/s-2002-20137. PMID 11842354. S2CID 26072420.*
25. ^ *Khodakarami, J. (2009). Achieving thermal comfort. VDM Verlag. ISBN 978-3-639-18292-7.*[*page needed*]
26. ^ Thermal Comfort chapter, Fundamentals volume of the ASHRAE Handbook, ASHRAE, Inc., Atlanta, GA, 2005[*page needed*]

27. ^ *Ainsworth, BE; Haskell, WL; Whitt, MC; Irwin, ML; Swartz, AM; Strath, SJ; O'Brien, WL; Bassett Jr, DR; Schmitz, KH; Emplaincourt, PO; Jacobs Jr, DR; Leon, AS (2000). "Compendium of physical activities: An update of activity codes and MET intensities". Medicine & Science in Sports & Exercise.* ***32*** *(9 Suppl): S498–504. CiteSeerX 10.1.1.524.3133. doi:10.1097/00005768-200009001-00009. PMID 10993420.*
28. ^ ***a b*** *Szokolay, Steven V. (2010). Introduction to Architectural Science: The Basis of Sustainable Design (2nd ed.). pp. 16–22.*
29. ^ *Havenith, G (1999). "Heat balance when wearing protective clothing". The Annals of Occupational Hygiene.* ***43*** *(5): 289–96. CiteSeerX 10.1.1.566.3967. doi:10.1016/S0003-4878(99)00051-4. PMID 10481628.*
30. ^ *McCullough, Elizabeth A.; Eckels, Steve; Harms, Craig (2009). "Determining temperature ratings for children's cold weather clothing". Applied Ergonomics.* ***40*** *(5): 870–7. doi:10.1016/j.apergo.2008.12.004. PMID 19272588.*
31. ^ *Frank C. Mooren, ed. (2012). "Skin Wettedness". Encyclopedia of Exercise Medicine in Health and Disease. p. 790. doi:10.1007/978-3-540-29807-6_3041. ISBN 978-3-540-36065-0.*
32. ^ *Fukazawa, Takako; Havenith, George (2009). "Differences in comfort perception in relation to local and whole-body skin wetness". European Journal of Applied Physiology.* ***106*** *(1): 15–24. doi:10.1007/s00421-009-0983-z. PMID 19159949. S2CID 9932558.*
33. ^ ***a b*** ANSI, ASHRAE, 2020. Standard – 55 Thermal environmental conditions for human occupancy.
34. ^ *Balaras, Constantinos A.; Dascalaki, Elena; Gaglia, Athina (2007). "HVAC and indoor thermal conditions in hospital operating rooms". Energy and Buildings.* ***39*** *(4): 454. doi:10.1016/j.enbuild.2006.09.004.*
35. ^ *Wolkoff, Peder; Kjaergaard, Søren K. (2007). "The dichotomy of relative humidity on indoor air quality". Environment International.* ***33*** *(6): 850–7. doi:10.1016/j.envint.2007.04.004. PMID 17499853.*
36. ^ *Hashiguchi, Nobuko; Tochihara, Yutaka (2009). "Effects of low humidity and high air velocity in a heated room on physiological responses and thermal comfort after bathing: An experimental study". International Journal of Nursing Studies.* ***46*** *(2): 172–80. doi:10.1016/j.ijnurstu.2008.09.014. PMID 19004439.*
37. ^ *McMullan, Randall (2012). Environmental Science in Building. Macmillan International Higher Education. p. 25. ISBN 9780230390355.*[*permanent dead link*]
38. ^ *"Humidity". Humidity. The Columbia Electronic Encyclopedia (6th ed.). Columbia University Press. 2012.*

39. ^ *"How the weather makes you hot and cold". Popular Mechanics. Hearst Magazines. July 1935. p. 36.*
40. ^ *Morris, Nathan B.; English, Timothy; Hospers, Lily; Capon, Anthony; Jay, Ollie (2019-08-06). "The Effects of Electric Fan Use Under Differing Resting Heat Index Conditions: A Clinical Trial". Annals of Internal Medicine.* ***171*** *(9). American College of Physicians: 675–677. doi:10.7326/m19-0512. ISSN 0003-4819. PMID 31382270. S2CID 199447588.*
41. ^ *"Radiation and Thermal Comfort for Indoor Spaces | SimScale Blog". SimScale. 2019-06-27. Retrieved 2019-10-14.*
42. ^ *Humphreys, Michael A.; Nicol, J. Fergus; Raja, Iftikhar A. (2007). "Field Studies of Indoor Thermal Comfort and the Progress of the Adaptive Approach". Advances in Building Energy Research.* ***1*** *(1): 55–88. doi:10.1080/17512549.2007.9687269. ISSN 1751-2549. S2CID 109030483.*
43. ^ *Brager, Gail S.; de Dear, Richard J. (1998). "Thermal adaptation in the built environment: a literature review". Energy and Buildings.* ***27*** *(1): 83–96. doi:10.1016/S0378-7788(97)00053-4. ISSN 0378-7788. S2CID 114893272.*
44. ^ *Hoyt, Tyler; Schiavon, Stefano; Piccioli, Alberto; Moon, Dustin; Steinfeld, Kyle (2013). "CBE Thermal Comfort Tool". Center for the Built Environment, University of California, Berkeley. Retrieved 21 November 2013.*
45. ^ ***a b*** *Cheung, Toby; Schiavon, Stefano; Parkinson, Thomas; Li, Peixian; Brager, Gail (2019-04-15). "Analysis of the accuracy on PMV – PPD model using the ASHRAE Global Thermal Comfort Database II". Building and Environment.* ***153****: 205–217. doi:10.1016/j.buildenv.2019.01.055. ISSN 0360-1323. S2CID 115526743.*
46. ^ *Földváry LiÃƒÆ’Ã†â€™Ãƒâ€ Ã¢â‚¬â„¢ÃƒÆ’Ã¢â‚¬Â ÃƒÂ¢Ã¢â€šÂ¬Ã¢â€žÂ¢ÃƒÆ’Ã†â€™ÃƒÂ¢Ã¢â€ Veronika; Cheung, Toby; Zhang, Hui; de Dear, Richard; Parkinson, Thomas; Arens, Edward; Chun, Chungyoon; Schiavon, Stefano; Luo, Maohui (2018-09-01). "Development of the ASHRAE Global Thermal Comfort Database II". Building and Environment.* ***142****: 502–512. doi:10.1016/j.buildenv.2018.06.022. hdl: 11311/1063927. ISSN 0360-1323. S2CID 115289014.*
47. ^ *WC16 Saberi (PDF). p. 1329 (p. 5 in the PDF). Archived from the original (PDF) on 23 June 2016. Retrieved 31 May 2017.*
48. ^ ***a b c*** *Gagge, AP; Fobelets, AP; Berglund, LG (1986). "A standard predictive index of human response to the thermal environment". ASHRAE Transactions.* ***92*** *(2nd ed.): 709–31.*
49. ^ ***a b*** *Doherty, TJ; Arens, E.A. (1988). "Evaluation of the physiological bases of thermal comfort models". ASHRAE Transactions.* ***94*** *(1): 15.*

50. **^** *Berglund, Larry (1978). "Mathematical models for predicting the thermal comfort response of building occupants". ASHRAE Transactions.* ***84****.*
51. **^** *Fountain, Mark; Huizenga, Charlie (1997). "A thermal sensation prediction software tool for use by the profession". ASHRAE Transactions.* ***103*** *(2).*
52. **^** La Roche, P. (2011). *Carbon-neutral architectural design*. CRC Press.[*page needed*]
53. **^** EN 15251 Standard 2007, Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics
54. ^ ***a b*** *Rohles, Frederick H. (February 2007). "Temperature & Temperament - A Psychologist Looks at Comfort". ASHRAE Journal: 14–22.*
55. ^ ***a b c*** *Szokolay, Steven V. (2010). Introduction to Architectural Science: The Basis of Sustainable Design (2nd ed.). p. 19.*
56. ^ ***a b*** *Nicol, J Fergus (2001). "Characterising Occupant Behaviour in Buildings" (PDF). Proceedings of the Seventh International IBPSA Conference. Rio de Janeiro, Brazil. pp. 1073–1078.*
57. **^** *Haldi, Frédéric; Robinson, Darren (2008). "On the behaviour and adaptation of office occupants". Building and Environment.* ***43*** *(12): 2163. doi:10.1016/j.buildenv.2008.01.003.*
58. ^ ***a b c*** *Lenzuni, P.; Freda, D.; Del Gaudio, M. (2009). "Classification of Thermal Environments for Comfort Assessment". Annals of Occupational Hygiene.* ***53*** *(4): 325–32. doi:10.1093/annhyg/mep012. PMID 19299555.*
59. **^** *Wyon, D.P.; Andersen, I.; Lundqvist, G.R. (2009). "Spontaneous magnitude estimation of thermal discomfort during changes in the ambient temperature*". Journal of Hygiene.* ***70*** *(2): 203–21. doi:10.1017/S0022172400022269. PMC 2130040. PMID 4503865.*
60. **^** *Karjalainen, Sami (2007). "Biological sex differences in thermal comfort and use of thermostats in everyday thermal environments". Building and Environment.* ***42*** *(4): 1594–1603. doi:10.1016/j.buildenv.2006.01.009.*
61. **^** *Lan, Li; Lian, Zhiwei; Liu, Weiwei; Liu, Yuanmou (2007). "Investigation of biological sex difference in thermal comfort for Chinese people". European Journal of Applied Physiology.* ***102*** *(4): 471–80. doi:10.1007/s00421-007-0609-2. PMID 17994246. S2CID 26541128.*
62. **^** *Harimi Djamila; Chi Chu Ming; Sivakumar Kumaresan (6–7 November 2012), "Assessment of Gender Differences in Their Thermal Sensations to the Indoor Thermal Environment", Engineering Goes Green, 7th CUTSE Conference, Sarawak Malaysia: School of Engineering & Science, Curtin University, pp. 262–266, ISBN 978-983-44482-3-3.*

63. ^ *Yu, Jinghua; Yang, Changzhi; Tian, Liwei; Liao, Dan (2009). "Evaluation on energy and thermal performance for residential envelopes in hot summer and cold winter zone of China". Applied Energy.* ***86*** *(10): 1970. doi:10.1016/j.apenergy.2009.01.012.*
64. ^ *Silva, Vicente de Paulo Rodrigues; De Azevedo, Pedro Vieira; Brito, Robson Souto; Campos, João Hugo Baracuy (2009). "Evaluating the urban climate of a typically tropical city of northeastern Brazil". Environmental Monitoring and Assessment.* ***161*** *(1–4): 45–59. doi:10.1007/s10661-008-0726-3. PMID 19184489. S2CID 23126235.*.
65. ^ United States Environmental Protection Agency. Office of Air and Radiation. Office of the Administrator.; Smart Growth Network (2003). *Smart Growth and Urban Heat Islands*. (EPA-content)
66. ^ *Shmaefsky, Brian R. (2006). "One Hot Demonstration: The Urban Heat Island Effect" (PDF). Journal of College Science Teaching.* ***35*** *(7): 52–54. Archived (PDF) from the original on 2022-03-16.*
67. ^ *Al-Homoud, Mohammad S.; Abdou, Adel A.; Budaiwi, Ismail M. (2009). "Assessment of monitored energy use and thermal comfort conditions in mosques in hot-humid climates". Energy and Buildings.* ***41*** *(6): 607. doi:10.1016/j.enbuild.2008.12.005.*
68. ^ Nasrollahi, N. (2009). *Thermal environments and occupant thermal comfort*. VDM Verlag, 2009, ISBN 978-3-639-16978-2.[*page needed*]
69. ^ *"About the WBGT and Apparent Temperature Indices".*
70. ^ *Hancock, P. A.; Ross, Jennifer M.; Szalma, James L. (2007). "A Meta-Analysis of Performance Response Under Thermal Stressors". Human Factors: The Journal of the Human Factors and Ergonomics Society.* ***49*** *(5): 851–77. doi:10.1518/001872007X230226. PMID 17915603. S2CID 17379285.*
71. ^ *Leon, Lisa R. (2008). "Thermoregulatory responses to environmental toxicants: The interaction of thermal stress and toxicant exposure". Toxicology and Applied Pharmacology.* ***233*** *(1): 146–61. doi:10.1016/j.taap.2008.01.012. PMID 18313713.*
72. ^ ISO, 2004. ISO 7933 – Ergonomics of the thermal environment — Analytical determination and interpretation of heat stress using calculation of the predicted heat strain.
73. ^ *"OSHA Technical Manual (OTM) Section III: Chapter 4". osha.gov. September 15, 2017. Retrieved January 11, 2024.*
74. ^ *Peeters, Leen; Dear, Richard de; Hensen, Jan; d'Haeseleer, William (2009). "Thermal comfort in residential buildings: Comfort values and scales for building energy simulation". Applied Energy.* ***86*** *(5): 772.*

doi:10.1016/j.apenergy.2008.07.011.

75. ^ Barwood, Martin J.; Newton, Phillip S.; Tipton, Michael J. (2009). "Ventilated Vest and Tolerance for Intermittent Exercise in Hot, Dry Conditions with Military Clothing". Aviation, Space, and Environmental Medicine. **80** (4): 353–9. doi:10.3357/ASEM.2411.2009. PMID 19378904.
76. ^ Zhang, Hui; Arens, Edward; Huizenga, Charlie; Han, Taeyoung (2010). "Thermal sensation and comfort models for non-uniform and transient environments: Part I: Local sensation of individual body parts". Building and Environment. **45** (2): 380. doi:10.1016/j.buildenv.2009.06.018. S2CID 220973362.
77. ^ Zhang, Hui; Arens, Edward; Huizenga, Charlie; Han, Taeyoung (2010). "Thermal sensation and comfort models for non-uniform and transient environments, part II: Local comfort of individual body parts". Building and Environment. **45** (2): 389. doi:10.1016/j.buildenv.2009.06.015.
78. ^ Zhang, Hui; Arens, Edward; Huizenga, Charlie; Han, Taeyoung (2010). "Thermal sensation and comfort models for non-uniform and transient environments, part III: Whole-body sensation and comfort". Building and Environment. **45** (2): 399. doi:10.1016/j.buildenv.2009.06.020.
79. ^ Tsushima, Yoshiaki; Okada, Sho; Kawai, Yuka; Sumita, Akio; Ando, Hiroshi; Miki, Mitsunori (10 August 2020). "Effect of illumination on perceived temperature". PLOS ONE. **15** (8): e0236321. Bibcode:2020PLoSO..1536321T. doi: 10.1371/journal.pone.0236321. PMC 7416916. PMID 32776987.
80. ^ Ziat, Mounia; Balcer, Carrie Anne; Shirtz, Andrew; Rolison, Taylor (2016). "A Century Later, the Hue-Heat Hypothesis: Does Color Truly Affect Temperature Perception?". Haptics: Perception, Devices, Control, and Applications. Lecture Notes in Computer Science. Vol. 9774. pp. 273–280. doi:10.1007/978-3-319-42321-0_25. ISBN 978-3-319-42320-3.
81. ^ "Hue Heat". Medium. 10 April 2022. Retrieved 15 May 2023.
82. ^ Toftum, Jørn; Thorseth, Anders; Markvart, Jakob; Logadóttir, Ásta (October 2018). "Occupant response to different correlated colour temperatures of white LED lighting" (PDF). Building and Environment. **143**: 258–268. doi:10.1016/j.buildenv.2018.07.013. S2CID 115803800.
83. ^ "Temperature - Colour - National 5 Art and Design Revision". BBC Bitesize. Retrieved 15 May 2023.
84. ^ Khodakarami, Jamal; Nasrollahi, Nazanin (2012). "Thermal comfort in hospitals – A literature review". Renewable and Sustainable Energy Reviews. **16** (6): 4071. doi:10.1016/j.rser.2012.03.054.
85. ^ **a b** Zhang, H.; Arens, E.; Zhai, Y. (2015). "A review of the corrective power of personal comfort systems in non-neutral ambient environments". Building and Environment. **91**: 15–41. doi:10.1016/j.buildenv.2015.03.013.

86. ^ *Andersen, M.; Fiero, G.; Kumar, S. (21–26 August 2016). "Well-Connected Microzones for Increased Building Efficiency and Occupant Comfort". Proceedings of ACEEE Summer Study on Energy Efficiency in Buildings.*

Further reading

[edit]

- *Thermal Comfort*, Fanger, P. O, Danish Technical Press, 1970 (Republished by McGraw–Hill, New York, 1973).
- Thermal Comfort chapter, Fundamentals volume of the *ASHRAE Handbook*, ASHRAE, Inc., Atlanta, GA, 2005.
- *Weiss, Hal (1998). Secrets of Warmth: For Comfort or Survival. Seattle, WA: Mountaineers Books. ISBN 978-0-89886-643-8. OCLC 40999076.*
- Godish, T. Indoor Environmental Quality. Boca Raton: CRC Press, 2001.
- Bessoudo, M. *Building Facades and Thermal Comfort: The impacts of climate, solar shading, and glazing on the indoor thermal environment.* VDM Verlag, 2008
- *Nicol, Fergus (2012). Adaptive thermal comfort : principles and practice. London New York: Routledge. ISBN 978-0415691598.*
- *Humphreys, Michael (2016). Adaptive thermal comfort : foundations and analysis. Abingdon, U.K. New York, NY: Routledge. ISBN 978-0415691611.*
- Communications in development and assembly of textile products, Open Access Journal, ISSN 2701-939X
- Heat Stress, National Institute for Occupational Safety and Health.
- Cold Stress, National Institute for Occupational Safety and Health.

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Heating, ventilation, and air conditioning

Fundamental concepts	◦ Air changes per hour ◦ Bake-out ◦ Building envelope ◦ Convection ◦ Dilution ◦ Domestic energy consumption ◦ Enthalpy ◦ Fluid dynamics ◦ Gas compressor ◦ Heat pump and refrigeration cycle ◦ Heat transfer ◦ Humidity ◦ Infiltration ◦ Latent heat ◦ Noise control ◦ Outgassing ◦ Particulates ◦ Psychrometrics ◦ Sensible heat ◦ Stack effect ◦ Thermal comfort ◦ Thermal destratification ◦ Thermal mass ◦ Thermodynamics ◦ Vapour pressure of water

Technology

- Absorption-compression heat pump
- Absorption refrigerator
- Air barrier
- Air conditioning
- Antifreeze
- Automobile air conditioning
- Autonomous building
- Building insulation materials
- Central heating
- Central solar heating
- Chilled beam
- Chilled water
- Constant air volume (CAV)
- Coolant
- Cross ventilation
- Dedicated outdoor air system (DOAS)
- Deep water source cooling
- Demand controlled ventilation (DCV)
- Displacement ventilation
- District cooling
- District heating
- Electric heating
- Energy recovery ventilation (ERV)
- Firestop
- Forced-air
- Forced-air gas
- Free cooling
- Heat recovery ventilation (HRV)
- Hybrid heat
- Hydronics
- Ice storage air conditioning
- Kitchen ventilation
- Mixed-mode ventilation
- Microgeneration
- Passive cooling
- Passive daytime radiative cooling

- Air conditioner inverter
- Air door
- Air filter
- Air handler
- Air ionizer
- Air-mixing plenum
- Air purifier
- Air source heat pump
- Attic fan
- Automatic balancing valve
- Back boiler
- Barrier pipe
- Blast damper
- Boiler
- Centrifugal fan
- Ceramic heater
- Chiller
- Condensate pump
- Condenser
- Condensing boiler
- Convection heater
- Compressor
- Cooling tower
- Damper
- Dehumidifier
- Duct
- Economizer
- Electrostatic precipitator
- Evaporative cooler
- Evaporator
- Exhaust hood
- Expansion tank
- Fan
- Fan coil unit
- Fan filter unit
- Fan heater

Measurement and control	◦ Air flow meter ◦ Aquastat ◦ BACnet ◦ Blower door ◦ Building automation ◦ Carbon dioxide sensor ◦ Clean air delivery rate (CADR) ◦ Control valve ◦ Gas detector ◦ Home energy monitor ◦ Humidistat ◦ HVAC control system ◦ Infrared thermometer ◦ Intelligent buildings ◦ LonWorks ◦ Minimum efficiency reporting value (MERV) ◦ Normal temperature and pressure (NTP) ◦ OpenTherm ◦ Programmable communicating thermostat ◦ Programmable thermostat ◦ Psychrometrics ◦ Room temperature ◦ Smart thermostat ◦ Standard temperature and pressure (STP) ◦ Thermographic camera ◦ Thermostat ◦ Thermostatic radiator valve

Professions, trades, and services	◦ Architectural acoustics ◦ Architectural engineering ◦ Architectural technologist ◦ Building services engineering ◦ Building information modeling (BIM) ◦ Deep energy retrofit ◦ Duct cleaning ◦ Duct leakage testing ◦ Environmental engineering ◦ Hydronic balancing ◦ Kitchen exhaust cleaning ◦ Mechanical engineering ◦ Mechanical, electrical, and plumbing ◦ Mold growth, assessment, and remediation ◦ Refrigerant reclamation ◦ Testing, adjusting, balancing
Industry organizations	◦ AHRI ◦ AMCA ◦ ASHRAE ◦ ASTM International ◦ BRE ◦ BSRIA ◦ CIBSE ◦ Institute of Refrigeration ◦ IIR ◦ LEED ◦ SMACNA ◦ UMC
Health and safety	◦ Indoor air quality (IAQ) ◦ Passive smoking ◦ Sick building syndrome (SBS) ◦ Volatile organic compound (VOC)

See also

- ASHRAE Handbook
- Building science
- Fireproofing
- Glossary of HVAC terms
- Warm Spaces
- World Refrigeration Day
- Template:Home automation
- Template:Solar energy

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About Modular building

For the Lego series, see Lego Modular Buildings.

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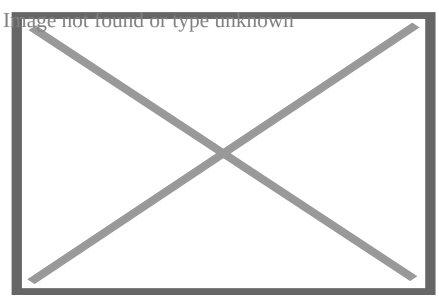
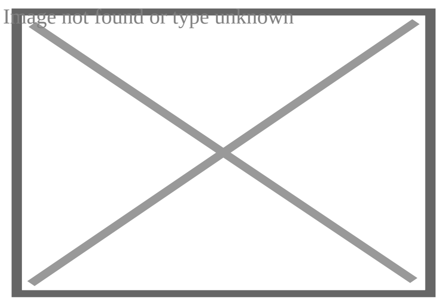


Prefabricated house in Valencia, Spain.

A **modular building** is a prefabricated building that consists of repeated sections called modules.[1] Modularity involves constructing sections away from the building site, then delivering them to the intended site. Installation of the prefabricated sections is completed on site. Prefabricated sections are sometimes placed using a crane. The modules can be placed side-by-side, end-to-end, or stacked, allowing for a variety of configurations and styles. After placement, the modules are joined together using inter-module connections, also known as inter-connections. The inter-connections tie the individual modules together to form the overall building structure.[2]

Uses

[edit]



Modular home prefab sections to be placed on the foundation

Modular buildings may be used for long-term, temporary or permanent facilities, such as construction camps, schools and classrooms, civilian and military housing, and industrial facilities. Modular buildings are used in remote and rural areas where conventional construction may not be reasonable or possible, for example, the Halley VI accommodation pods used for a BAS Antarctic expedition.[3] Other uses have included churches, health care facilities, sales and retail offices, fast food restaurants and cruise ship construction. They can also be used in areas that have weather concerns, such as hurricanes. Modular buildings are often used to provide temporary facilities, including toilets and ablutions at events. The portability of the buildings makes them popular with hire companies and clients alike. The use of modular buildings enables events to be held at locations where existing facilities are unavailable, or unable to support the number of event attendees.

Construction process

[edit]

Construction is offsite, using lean manufacturing techniques to prefabricate single or multi-story buildings in deliverable module sections. Often, modules are based around standard 20 foot containers, using the same dimensions, structures, building and stacking/placing techniques, but with smooth (instead of corrugated) walls, glossy white paint, and provisions for windows, power, potable water, sewage lines, telecommunications and air conditioning. Permanent Modular Construction (PMC) buildings are manufactured in a controlled setting and can be constructed of wood, steel, or concrete. Modular components are typically constructed indoors on assembly lines. Modules' construction may take as little as ten days but more often one to three months. PMC modules can be integrated into site built projects or stand alone and can be delivered with MEP, fixtures and interior finishes.

The buildings are 60% to 90% completed offsite in a factory-controlled environment, and transported and assembled at the final building site. This can comprise the entire building or be components or subassemblies of larger structures. In many cases, modular contractors work with traditional general contractors to exploit the resources and advantages of each type of construction. Completed modules are transported to the building site and assembled by a crane.[4] Placement of the modules may take from several hours to several days. Off-site construction running in parallel to site preparation providing a shorter time to project completion is one of the common selling points of modular construction. Modular construction timeline

Permanent modular buildings are built to meet or exceed the same building codes and standards as site-built structures and the same architect-specified materials used in conventionally constructed buildings are used in modular construction projects. PMC can have as many stories as building codes allow. Unlike relocatable buildings, PMC structures are intended to remain in one location for the duration of their useful life.

Manufacturing considerations

[edit]

The entire process of modular construction places significance on the design stage. This is where practices such as Design for Manufacture and Assembly (DfMA) are used to ensure that assembly tolerances are controlled throughout manufacture and assembly on site. It is vital that there is enough allowance in the design to allow the assembly to take up any "slack" or misalignment of components. The use of advanced CAD systems, 3D printing and manufacturing control systems are important for modular construction to be successful. This is quite unlike on-site construction where the tradesman can often make the part to suit any particular installation.

Bulk materials

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  Bulk
  materials
  Walls attached to floor

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  Walls attached to
  floor
  Ceiling drywalled in spray booth

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  Ceiling drywalled in
  spray booth

Roof set in place

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  Roof set in place
  Roof shingled and siding installed

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  Roof shingled and
  siding installed
  Ready for delivery to site

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  Ready for delivery
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  Two-story modular dwelling

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  Two-story modular dwelling
  Pratt Modular Home in Tyler Texas

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  Tyler Texas

Pratt Modular Home kitchen

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  Pratt Modular Home in Tyler Texas

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Upfront production investment

[edit]

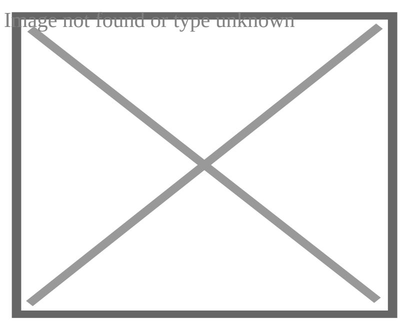
The development of factory facilities for modular homes requires significant upfront investment. To help address housing shortages in the 2010s, the United Kingdom Government (via Homes England) invested in modular housing initiatives. Several UK companies (for example, Ilke Homes, L&G Modular Homes, House by Urban Splash, Modulous, TopHat and Lighthouse) were established to develop modular homes as an alternative to traditionally-built residences, but failed as they could not book revenues quickly enough to cover the costs of establishing manufacturing facilities.

Ilke Homes opened a factory in Knaresborough, Yorkshire in 2018, and Homes England invested £30m in November 2019,[5] and a further £30m in September 2021.[6] Despite a further fund-raising round, raising £100m in December 2022,[7][8] Ilke Homes went into administration on 30 June 2023,[9][10] with most of the company's 1,150 staff made redundant,[11] and debts of £320m,[12] including £68m owed to Homes England.[13]

In 2015 Legal & General launched a modular homes operation, L&G Modular Homes, opening a 550,000 sq ft factory in Sherburn-in-Elmet, near Selby in Yorkshire.[14] The company incurred large losses as it invested in its factory before earning any revenues; by 2019, it had lost over £100m.[15] Sales revenues from a Selby project, plus schemes in Kent and West Sussex, started to flow in 2022, by which time the business's total losses had grown to £174m.[16] Production was halted in May 2023, with L&G blaming local planning delays and the COVID-19 pandemic for its failure to grow its sales pipeline.[17][18] The enterprise incurred total losses over seven years of £295m.[19]

Market acceptance

[edit]



Raines Court is a multi-story modular housing block in Stoke Newington, London, one of the first two residential buildings in Britain of this type. (December 2005)

Some home buyers and some lending institutions resist consideration of modular homes as equivalent in value to site-built homes.[*citation needed*] While the homes themselves may be of equivalent quality, entrenched zoning regulations and psychological marketplace factors may create hurdles for buyers or builders of modular homes and should be considered as part of the decision-making process when exploring this type of home as a living and/or investment option. In the UK and Australia, modular homes have become accepted in some regional areas; however, they are not commonly built in major cities. Modular homes are becoming increasingly common in Japanese urban areas, due to improvements in design and quality, speed and compactness of onsite assembly, as well as due to lowering costs and ease of repair after earthquakes. Recent innovations allow modular buildings to be indistinguishable from site-built structures.[20] Surveys have shown that individuals can rarely tell the difference between a modular home and a site-built home.[21]

Modular homes vs. mobile homes

[edit]

Differences include the building codes that govern the construction, types of material used and how they are appraised by banks for lending purposes. Modular homes are built to either local or state building codes as opposed to manufactured homes, which are also built in a factory but are governed by a federal building code.[22] The codes that govern the construction of modular homes are exactly the same codes that govern the construction of site-constructed homes.[*citation needed*] In the United States, all modular homes are constructed according to the International Building Code (IBC), IRC, BOCA or the code that has been adopted by the local jurisdiction.[*citation needed*] In some states, such as California, mobile homes must still be registered yearly, like vehicles or standard trailers, with the Department of Motor Vehicles or other state agency. This is true even if the owners remove the axles and place it on a permanent foundation.[23]

Recognizing a mobile or manufactured home

[edit]

A mobile home should have a small metal tag on the outside of each section. If a tag cannot be located, details about the home can be found in the electrical panel box. This tag should also reveal a manufacturing date.[*citation needed*] Modular homes do not have metal tags on the outside but will have a dataplate installed inside the home, usually under the kitchen sink or in a closet. The dataplate will provide information such as the manufacturer, third party inspection agency, appliance information, and manufacture date.

Materials

[edit]

The materials used in modular buildings are of the same quality and durability as those used in traditional construction, preserving characteristics such as acoustic insulation and energy efficiency, as well as allowing for attractive and innovative designs thanks to their versatility.[24] Most commonly used are steel, wood and concrete.[25]

- Steel: Because it is easily moldable, it allows for innovation in design and aesthetics.
- Wood: Wood is an essential part of most modular buildings. Thanks to its lightness, it facilitates the work of assembling and moving the prefabricated modules.
- Concrete: Concrete offers a solid structure that is ideal for the structural reinforcement of permanent modular buildings. It is increasingly being used as a base material in this type of building, thanks to its various characteristics such as fire resistance, energy savings, greater acoustic insulation, and durability.[26]

Wood-frame floors, walls and roof are often utilized. Some modular homes include brick or stone exteriors, granite counters and steeply pitched roofs. Modulars can be designed to sit on a perimeter foundation or basement. In contrast, mobile homes are constructed with a steel chassis that is integral to the integrity of the floor system. Modular buildings can be custom built to a client's specifications. Current designs include multi-story units, multi-family units and entire apartment complexes. The negative stereotype commonly associated with mobile homes has prompted some manufacturers to start using the term "off-site construction."

New modular offerings include other construction methods such as cross-laminated timber frames.[27]

Financing

[edit]

Mobile homes often require special lenders.[28]

Modular homes on the other hand are financed as site built homes with a construction loan

Standards and zoning considerations

[edit]

Typically, modular dwellings are built to local, state or council code, resulting in dwellings from a given manufacturing facility having differing construction standards depending on the final destination of the modules.[29] The most important zones that manufacturers have to take into consideration are local wind, heat, and snow load zones.[*citation needed*] For example, homes built for final assembly in a hurricane-prone, earthquake or flooding area may include additional bracing to meet local building codes. Steel and/or wood framing are common options for building a modular home.

Some US courts have ruled that zoning restrictions applicable to mobile homes do not apply to modular homes since modular homes are designed to have a permanent foundation.[*citation needed*] Additionally, in the US, valuation differences between modular homes and site-built homes are often negligible in real estate appraisal practice; modular homes can, in some market areas, (depending on local appraisal practices per Uniform Standards of Professional Appraisal Practice) be evaluated the same way as site-built dwellings of similar quality. In Australia, manufactured home parks are governed by additional legislation that does not apply to permanent modular homes. Possible developments in equivalence between modular and site-built housing types for the purposes of real estate appraisals, financing and zoning may increase the sales of modular homes over time.[30]

CLASP (Consortium of Local Authorities Special Programme)

[edit]

The Consortium of Local Authorities Special Programme (abbreviated and more commonly referred to as CLASP) was formed in England in 1957 to combine the resources of local authorities with the purpose of developing a prefabricated school building programme. Initially developed by Charles Herbert Aslin, the county architect for Hertfordshire, the system was used as a model for several other counties, most notably Nottinghamshire and Derbyshire. CLASP's popularity in these coal mining areas was in part because the system permitted fairly straightforward replacement of subsidence-damaged sections of building.

Building strength

[edit]

Modular Home being built in Vermont photo by Josh Vignona

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Modular home in Vermont

Modular homes are designed to be stronger than traditional homes by, for example, replacing nails with screws, adding glue to joints, and using 8–10% more lumber than conventional housing.[[31]] This is to help the modules maintain their structural integrity as they are transported on trucks to the construction site. However, there are few studies on the response of modular buildings to transport and handling stresses. It is therefore presently difficult to predict transport induced damage.[[1]]

When FEMA studied the destruction wrought by Hurricane Andrew in Dade County Florida, they concluded that modular and masonry homes fared best compared to other construction.[32]

CE marking

[edit]

The CE mark is a construction norm that guarantees the user of mechanical resistance and strength of the structure. It is a label given by European community empowered authorities for end-to-end process mastering and traceability.[*citation needed*]

All manufacturing operations are being monitored and recorded:

- Suppliers have to be known and certified,
- Raw materials and goods being sourced are to be recorded by batch used,
- Elementary products are recorded and their quality is monitored,
- Assembly quality is managed and assessed on a step by step basis,
- When a modular unit is finished, a whole set of tests are performed and if quality standards are met, a unique number and EC stamp is attached to and on the unit.

This ID and all the details are recorded in a database, At any time, the producer has to be able to answer and provide all the information from each step of the production of a single unit, The EC certification guaranties standards in terms of durability, resistance against wind and earthquakes.[*citation needed*]

Open modular building

[edit]
See also: Green building

The term Modularity can be perceived in different ways. It can even be extended to building P2P (peer-to-peer) applications; where a tailored use of the P2P technology is with the aid of a modular paradigm. Here, well-understood components with clean interfaces can be combined to implement arbitrarily complex functions in the hopes of further proliferating self-organising P2P technology. Open modular buildings are an excellent example of this. Modular building can also be open source and green. Bauwens, Kostakis and Pazaitis[33] elaborate on this kind of modularity. They link modularity to the construction of houses.

This commons-based activity is geared towards modularity. The construction of modular buildings enables a community to share designs and tools related to all the different parts of house construction. A socially-oriented endeavour that deals with the external architecture of buildings and the internal dynamics of open source commons. People are thus provided with the tools to reconfigure the public sphere in the area where they live, especially in urban environments. There is a robust socializing element that is reminiscent of pre-industrial vernacular architecture and community-based building.[34]

Some organisations already provide modular housing. Such organisations are relevant as they allow for the online sharing of construction plans and tools. These plans can be then assembled, through either digital fabrication like 3D printing or even sourcing low-cost materials from local communities. It has been noticed that given how easy it is to use these low-cost materials are (for example: plywood), it can help increase the permeation of these open buildings to areas or communities that lack the know-how or abilities of conventional architectural or construction firms. Ergo, it allows for a fundamentally more standardised way of constructing houses and buildings. The overarching idea behind it remains key - to allow for easy access to user-friendly layouts which anyone can use to build in a more sustainable and affordable way.

Modularity in this sense is building a house from different standardised parts, like solving a jigsaw puzzle.

3D printing can be used to build the house.

The main standard is OpenStructures and its derivative Autarkytecture.[35]

Research and development

[edit]

Modular construction is the subject of continued research and development worldwide as the technology is applied to taller and taller buildings. Research and development is carried out by modular building companies and also research institutes such as the Modular Building Institute[36] and the Steel Construction Institute.[37]

See also

[edit]

- Image not found or type unknown Housing portal
- Affordable housing
- Alternative housing
- Commercial modular construction
- Construction 3D printing
- Container home
- Kit house
- MAN steel house
- Manufactured housing
- Modern methods of construction
- Modular design
- Portable building
- Prefabrication
- Open-source architecture
- Open source hardware
- OpenStructures
- Prefabricated home
- Relocatable buildings
- Recreational vehicles
- Shipping container architecture

- Stick-built home
- Tiny house movement
- Toter

References

[edit]

1. ^ ***a b*** *Lacey, Andrew William; Chen, Wensu; Hao, Hong; Bi, Kaiming (2018). "Structural Response of Modular Buildings – An Overview". Journal of Building Engineering.* ***16****: 45–56. doi:10.1016/j.jobe.2017.12.008. hdl:20.500.11937/60087.*
2. **^** *Lacey, Andrew William; Chen, Wensu; Hao, Hong; Bi, Kaiming (2019). "Review of bolted inter-module connections in modular steel buildings". Journal of Building Engineering.* ***23****: 207–219. doi:10.1016/j.jobe.2019.01.035. S2CID 86540434.*
3. **^** *"Halley VI Research Station – British Antarctic Survey". Bas.ac.uk. Retrieved 2016-05-03.*
4. **^** *"Why Build Modular?". Modular.org. Retrieved 2016-05-03.*
5. **^** *Morby, Aaron (4 November 2019). "Government pumps £30m into modular house builder". Construction Enquirer. Retrieved 14 March 2024.*
6. **^** *Morby, Aaron (27 September 2021). "Ilke Homes raises £60m for top 10 house builder plan". Construction Enquirer. Retrieved 14 March 2024.*
7. **^** *Morby, Aaron (6 December 2022). "Ilke Homes pulls off £100m record-breaking fund raise". Construction Enquirer. Retrieved 14 March 2024.*
8. **^** *O'Connor, Rob (6 December 2022). "ilke Homes announces new £100m investment". Infrastructure Intelligence. Retrieved 14 March 2024.*
9. **^** *Gardiner, Joey (30 June 2023). "Ilke Homes sinks into administration with most of firm's 1,100 staff set to lose their jobs". Building. Retrieved 14 March 2024.*
10. **^** *Riding, James (30 June 2023). "Modular house builder Ilke Homes enters administration with majority of staff to be made redundant". Inside Housing. Retrieved 14 March 2024.*
11. **^** *Morby, Aaron (30 June 2023). "Ilke Homes falls into administration". Construction Enquirer. Retrieved 14 March 2024.*
12. **^** *Prior, Grant (25 August 2023). "Ilke Homes went under owing £320m". Construction Enquirer. Retrieved 14 March 2024.*
13. **^** *Willmore, James (14 February 2024). "Homes England to lose most of £68.8m it is owed from Ilke Homes following collapse". Inside Housing. Retrieved 14 March 2024.*
14. **^** *Dale, Sharon (11 May 2020). "Head of Legal & General modular homes factory reveals plans for its future". Yorkshire Post. Retrieved 20 March 2024.*

15. ^ *Morby, Aaron (30 November 2020). "L&G modular homes losses exceed £100m". Construction Enquirer. Retrieved 20 March 2024.*
16. ^ *Morby, Aaron (3 October 2022). "L&G modular homes amassed loss deepens to £174m". Construction Enquirer. Retrieved 20 March 2024.*
17. ^ *Prior, Grant (4 May 2023). "L&G halts production at modular homes factory". Construction Enquirer. Retrieved 20 March 2024.*
18. ^ *Kollewe, Julia (4 May 2023). "Legal & General halts new production at modular homes factory near Leeds". The Guardian.*
19. ^ *Morby, Aaron (6 November 2023). "L&G modular homes foray amassed £295m of losses". Construction Enquirer. Retrieved 20 March 2024.*
20. ^ *fab, ukporta (19 August 2020). "prefabricated structures". ukportaprefab. Retrieved 4 September 2020.*
21. ^ *"Factory-Built Construction and the American Homebuyer: Perceptions and Opportunities" (PDF). Huduser.gov. p. 9. Retrieved 2017-09-10.*
22. ^ *Solutions, Dryside Property – Jennifer Mitchell and Magic Web. "Mobile homes vs Manufactured homes vs Modular homes". Drysideproperty.com. Retrieved 2018-03-09.*
23. ^ *"HCD Manufactured and Mobile Homes". Hcd.ca.gov.*
24. ^ Métodos modernos de construcción (MMC): Fabricación modular. Upv.es. 2020-10-02 Retrieved 2022-09-08
25. ^ A guide to the latest modular building construction materials. Hydrodiseno.com. 2021-12-14 Retrieved 2022-09-05
26. ^ Construcción modular en hormigón: una tendencia al alza (PDF). Andece.org. p. 53. Retrieved 2022-07-06
27. ^ *"Prefabricated Housing Module Advances Wood Research at the University of British Columbia | 2017-05-15T00:00:00 | Perkins + Will News". Archived from the original on 2019-03-31. Retrieved 2019-03-31.*
28. ^ *"HUD Financing Manufactured (Mobile) Homes". Portal.hud.gov. Archived from the original on 2016-05-03. Retrieved 2016-05-03.*
29. ^ *"Australian Government modular home regulations". Austlii.edu.au. Retrieved 2007-10-21.*
30. ^ *"Building Codes for Modular Homes". Modularhomesnetwork.com. Retrieved 2010-08-06.*
31. ^ *"Disruptive Development: Modular Manufacturing In Multifamily Housing" (PDF). p. 35. Retrieved 10 September 2017.*

32. ^ *"FIA 22, Mitigation Assessment Team Report: Hurricane Andrew in Florida (1993)". Fema.gov.*
33. ^ Bouwens, M., Kostakis, V., & Pazaitis, A. 2019. The Commons Manifesto. University of Westminster Press, London, pg. 24
34. ^ Bouwens, M., Kostakis, V., & Pazaitis, A. 2019. The Commons Manifesto. University of Westminster Press, London, pg. 25
35. ^ *"Thomas Lommée & Christiane Hoegner - Autarkytecture | z33". Archived from the original on 2014-12-31. Retrieved 2015-01-01.*
36. ^ *"Modular Building Institute". Modular.org.*
37. ^ *"The Steel Construction Institute (SCI) UK Global Steel Expertise". Steel-sci.com.*

34 – "Volumetric modular construction trend gaining groun d". https://www.aa.com.tr/en/corporate-news/volumetric-modular-construction-trend-gaining-ground/2357158 06.09.2021

Portal:

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About Durham Supply Inc

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Things To Do in Tulsa County

Photo

Tulsa Air and Space Museum & Planetarium

4.3 (419)

Photo

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Philbrook Museum of Art

4.8 (3790)

Photo

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Route 66 Historical Village

4.4 (718)

Photo

The Blue Dome

4.5 (60)

Photo

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OkieTundra

4.5 (84)

Photo

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Oxley Nature Center

4.8 (563)

Driving Directions in Tulsa County

Driving Directions From Nights Stay Hotel to Durham Supply Inc

Driving Directions From OYO Hotel Tulsa International Airport to Durham Supply Inc

Driving Directions From Waffle House to Durham Supply Inc

Driving Directions From Camp Bow Wow to Durham Supply Inc

Driving Directions From Brookhaven Hospitales to Durham Supply Inc

Driving Directions From Oakwood Homes to Durham Supply Inc

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Driving Directions From Blue Whale of Catoosa to Durham Supply Inc

Driving Directions From Oxley Nature Center to Durham Supply Inc

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Driving Directions From The Outsiders House Museum to Durham Supply Inc

Driving Directions From Gathering Place to Durham Supply Inc

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Reviews for Durham Supply Inc

Durham Supply Inc

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Dennis Champion

(5)

Durham supply and Royal supply seems to find the most helpful and friendly people to work in their stores, we are based out of Kansas City out here for a few remodels and these guys treated us like we've gone there for years.

Durham Supply Inc

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B Mann

(5)

I was in need of some items for a double wide that I am remodeling and this place is the only place in town that had what I needed (I didn't even try the other rude place)while I was there I learned the other place that was in Tulsa that also sold mobile home supplies went out of business (no wonder the last time I was in there they were VERY RUDE and high priced) I like the way Dunham does business they answered all my questions and got me the supplies I needed, very friendly, I will be back to purchase the rest of my items when the time comes.

Durham Supply Inc

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Ty Spears

(5)

Bought a door/storm door combo. Turns out it was the wrong size. They swapped it out, quick and easy no problems. Very helpful in explaining the size differences from standard door sizes.

Considering UV Technology for Mobile Home Air Treatment**View GBP**

Frequently Asked Questions

How does UV technology work in mobile home HVAC systems for air treatment?

UV technology uses ultraviolet light to kill or deactivate microorganisms such as bacteria, viruses, and mold spores. When installed in the HVAC system of a mobile home, it helps purify the circulated air by targeting these contaminants as they pass through the system.

What are the benefits of using UV technology in a mobile homes HVAC system?

The benefits include improved indoor air quality, reduced risk of respiratory infections, decreased odors caused by microbial growth, and potentially enhanced efficiency of the HVAC system by keeping components like coils cleaner.

Are there any safety concerns associated with installing UV lights in a mobile home HVAC system?

Properly installed and maintained UV lights are generally safe. However, direct exposure to UV-C light can be harmful to skin and eyes. Its important that they are installed within the ductwork or air handler where direct contact is minimized.

How often do UV lamps need to be replaced in an HVAC system for optimal performance?

Typically, UV lamps should be replaced every 9-12 months depending on usage and manufacturer recommendations to ensure effective microbial control.

Is integrating UV technology into a mobile homes existing HVAC system complicated or expensive?

Installing UV lights can be relatively straightforward if performed by a professional. Costs vary based on system size and specific requirements but generally range from $100 to $500 for parts and installation.

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State : OK

Zip : 73149

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