出國報告：(出國類別：考察)

赴捷克及義大利執行「歐盟都市災防應變與建築風環境先進試驗技術參訪觀摩研習計畫」

服務機關：內政部建築研究所
姓名職稱：陳建忠組長、郭建源副研究員
派赴國家：捷克、義大利
出國期間：**108** 年 **10** 月 **14** 日至 **10** 月 **23** 日
報告日期：**109** 年 **1** 月 **17** 日

摘　　要

關鍵詞：風工程、風環境、風洞試驗

本次出國赴捷克及義大利執行「歐盟都市災防應變與建築風環境先進試驗技術參訪觀摩研習計畫」，除拜訪捷克 UCEEB 實驗室及捷克理工大學土木工程學院室內環境與建築工程設備系，主要考察捷克科學研究院理論與應用力學所(ITAM)之環境風洞實驗室；義大利米蘭理工大學的 GVPM 風洞實驗室及佛羅倫斯大學營建與風工程氣動力學研究中心 CRIACIV 之大氣邊界層風洞實驗室等 3 個風洞實驗室。瞭解其風工程發展與建築風環境相關課題研究趨勢，作為我國在預防風災與建築環境舒適性應用之參考。觀摩風洞試驗先進技術與借鏡其營運模式，俾本所風雨風洞實驗室技術開發與實驗室永續發展之參考。並提升開發新型式的試驗方法可行性，以因應氣候變遷與產業需求變異下，發展合宜的技術規範與試驗技術。同時，具體規劃我國風工程科技的優先順序與未來來方向，俾使與國際趨勢接軌。

目　次

壹、目的

臺灣地理位置特殊，位於西太平洋颱風行進路徑上，根據統計平均每年 3 個颱風經過臺灣，強風伴隨豪雨常引致嚴重災情；而風也可促進自然通風或轉為潔淨能源減少碳排。所以，瞭解風制御風不但可以防災亦可節能與增能。惟我國風工程研究的起步較晚，目前「建築物耐風設計規範及解說」之內容主要參考美日等先進國家規範，部分則為國內專家學者執行本土化風洞試驗成果，綜合研擬而成。為提升我國風工程研究與試驗技術水準，持續自主精進我國耐風設計規範，以儘速迎上先進國家。內政部建築研究所科技計畫-「建築工程技術發展與整合應用計畫」，執行「風工程技術創新多元應用研究」分項計畫，致力於風工程研究。同時，本所風雨風洞實驗室專責於風工程相關研究發展與試驗驗證，過去應用相關試驗設備與技術，已完成部份技術規範本土化的修正，並開發相關應用軟體。但氣候異常與極端氣候頻繁出現，加上國內社會與業界需求轉變，現有規範內容與試驗設備恐無法因應未來天遽變氣型態與產業需求，須於既有基礎上再作適度的調整與更新。

由於風工程所涉及的專業領域甚廣，且研究與分析所需的應用工具需求多，若能開發新型的量測技術，可簡化分析或計算的複雜度，並且增加驗證效率，將有於風工程試驗發展。因此，本次出國赴捷克及義大利執行「歐盟都市災防應變與建築風環境先進試驗技術參訪觀摩研習計畫」，參訪相關試驗機構，瞭解其風工程發展與建築風環境相關課題研究趨勢，作為我國在預防風災與建築環境舒適性應用之參考。觀摩風洞試驗先進技術與借鏡其營運模式，俾本所風雨風洞實驗室技術開發與實驗室永續發展之參考。並提升開發新型式的試驗方法可行性，以因應氣候變遷與產業需求變異下，發展合宜的技術規範與試驗技術。同時，具體規劃我國風工程科技的優先順序與未來來方向，俾使與國際趨勢接軌。

貳、過程

本次出國計畫主要赴捷克及義大利執行「歐盟都市災防應變與建築風環境先進試驗技術參訪觀摩研習計畫」，依規劃時程拜訪捷克科學研究院理論與應用力學所之環境風洞實驗室，參觀捷克UCEEB實驗室及捷克理工大學土木工程學院室內環境與建築工程設備系；義大利則是至米蘭觀摩義大利Politecnico大學的GVPM 風洞實驗室、及佛羅倫斯大學營建與風工程氣動力學研究中心之大氣邊界層風洞實驗室。出國時間為108年10月14日至10月23日共計10天，行程安排如表1所示。

表 1、本次出國計畫行程表

日　　期	行　　程	任　　務
10 月 14 日 (一)	臺灣(桃園)→奧地利(維也納)	出發
10 月 15 日 (二)	奧地利(維也納) → 捷克(布拉格)	路程
10 月 16 日 (三)	捷克(布拉格)	參訪捷克科學研究院理論與應用力學所之環境風洞實驗室，瞭解該實驗室先進風雨效應模擬與量測及可視化技術，作為本所實驗室發展之參考。
10 月 17 日 (四)	捷克(布拉格)	參訪捷克 UCEEB(建築節能中心)實驗室，觀摩該中心相關建築環境研究設備。
10 月 18 日 (五)	捷克(布拉格)	參觀捷克理工大學土木工程學院室內環境與建築工程設備系，瞭解該系所於通風環境議題的研究課題與發展現況。
10 月 19 日 (六)	捷克(布拉格) →義大利（米蘭）	路程（搭飛機前往義大利）
10 月 20 日 (日)	義大利（米蘭）	GVPM 風洞實驗室路勘
10 月 21 日 (一)	義大利(佛羅倫斯）	參觀義大利 Politecnico 大學的 GVPM 風洞實驗室，該實驗室為一封閉式循環風洞，內有兩個測試段，瞭解各類建築、構造及設施設備與風場相關之耐風測試情形。 路程（前往佛羅倫斯）
10 月 22 日 (二)	義大利（羅馬）	拜訪佛羅倫斯大學營建與風工程氣動力學研究中心，參觀該中心之風洞實驗室，討論國際風工程與風洞實驗最新發展趨勢，並瞭解實驗室運作規模與人員配置情況。 路程（前往羅馬）
10 月 23 日 (三)	義大利（羅馬）→臺灣(桃園)	返程

一、參訪捷克科學研究院理論與應用力學所（ITAM）之環境風洞實驗室

(一) 環境風洞實驗室（Climatic Wind Engineering Laboratory）介紹

捷克科學研究院理論與應用力學所(Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences)設計為具有可控風速和溫度條件的封閉迴路，它分為環境和空氣動力兩個測試段。空氣動力測試段為研究風對縮尺模型原型的影響提供了合適的條件，而環境部分的設備則適合於研究天氣的影響，包括風，溫度，雨水和熱輻射。使用冷卻/熱交換器，在相對較短的時間段內，整個隧道內的空氣循環溫度變化可在-10 至 30 ℃的範圍內進行。 隧道設備的組成部分包括用於氣流診斷的儀器，數據採集系統，表面壓力直接測量，精確測溫以及許多其他類型方便使用的配件。 同一建築物中設有製造測試模型的講習班。

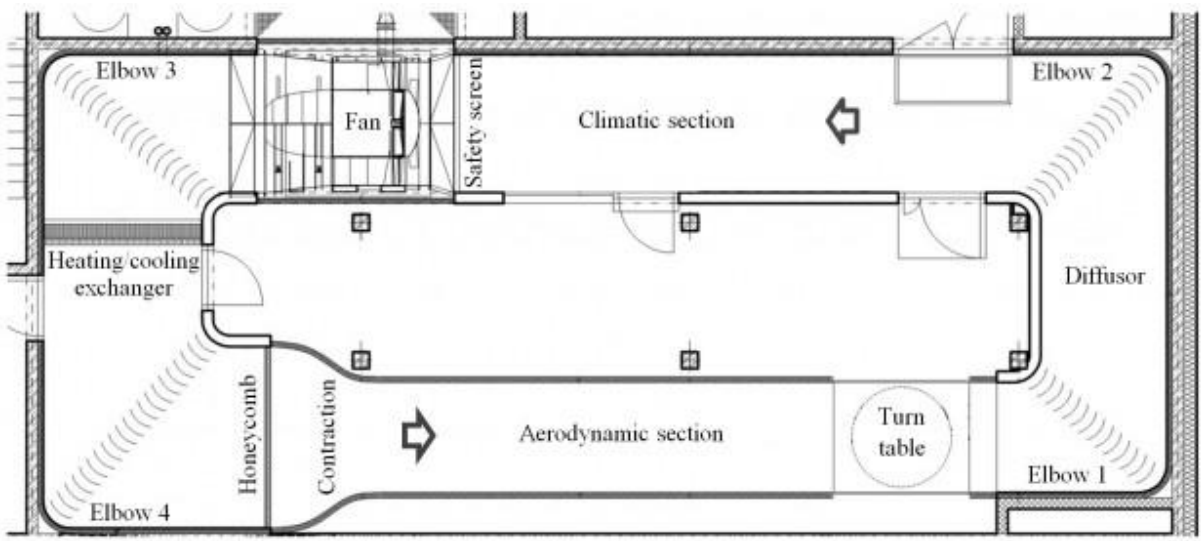


圖 1 捷克 ITAM 風洞剖面圖

Climatic Section –環境測試段主要執行與工程問題研究相關的實驗，包括土木工程，建築，文物保護以及其他出現風影響以及諸如凍結，輻射熱或雨等其他因素的領域中的。測試段的斷面為 2.5×3.9 m 的矩形截面，長度為 9.0 m。 在此部分中，風速為 0.8 到 18 m / s（取決於可垂直移動的天花板和流量噴嘴的位置）。 調節降雨強度和水滴大小，以模擬與毛毛雨或大雨相對應的效果。 可提供帶有四個總功率為 8 kW 的紅外線的輻射系統，並且最大入射角為 60°。 可以完全調節功率，一個按鈕即可操作。

圖 2 捷克 ITAM 風洞內部地況及風扇

氣動力測試段主要研究風對結構影響、風特性、局部風環境、行人的舒適度、空氣彈性結構響應、擴散、污染物擴散和物質傳輸，風對建築物熱損失和通風的影響，風對運輸系統的影響及風力發電等。空氣動力測試段硬體包括具有蜂巢網的加速段和放置測試件的旋轉台。測試段的橫斷面為 1.9×1.8 m 的矩形。 包括紊流產生器在內，測試段的總長度為 11.0 m。在測試段內運用角錐、格柵、障礙物和地面粗糙元等設備，模擬大氣邊層所需的紊流場特性。空風洞的風速範圍為 1.5 ~33 m / s。

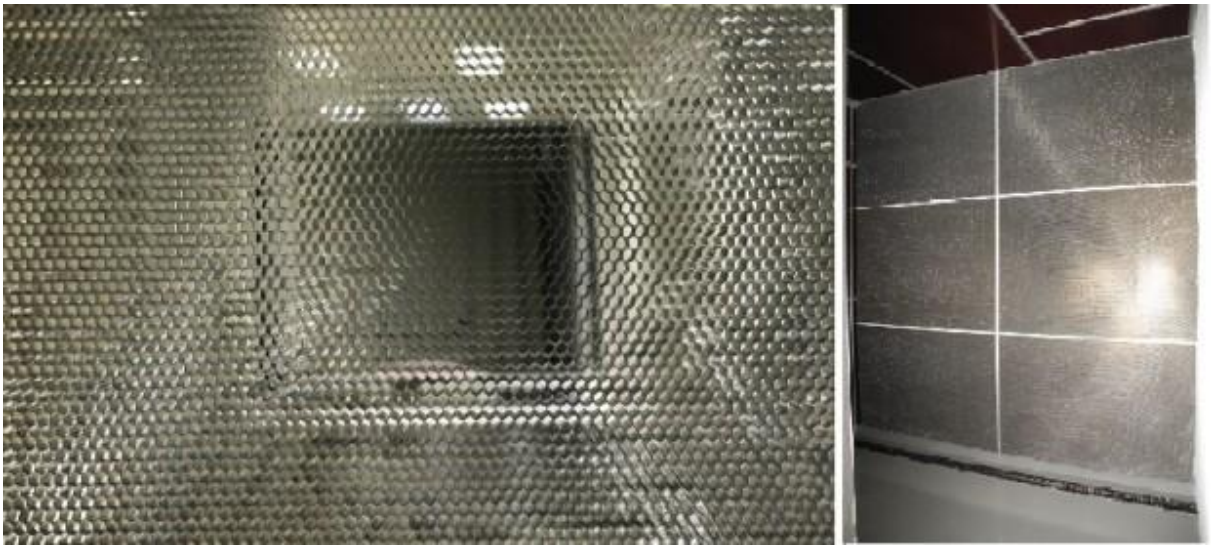


圖 3 捷克 ITAM 風洞蜂巢網

儀器設備包括如下：

· PIV (Particle Image Velocimetry) 粒子圖像測速儀–是一種非侵入式圖像的測量技術，用於速度模式診斷，包括紊流，微流體和噴霧分佈等。

· DEWETRON – 可同步採樣的現代化數據採集系統，提供 24 位 A / D 轉換以及抗混疊濾波和一流的信號調節功能。可通過進階後處理工具用於分析和數據訊號擷取。且可單獨與壓力傳感器進行壓力測量，也可與其他動態測量（例如電位計，應變計等）結合使用。共提供 32 個模擬通道。

圖 4 捷克 ITAM 風洞橋面版模型

· Traverse System Dantec - auxiliary instrument for accurate spatial mapping of measured position in the wind flow.

· Pressure Scanner Scanivalve 多頻道電子式壓力掃瞄 - mean value based pressure transducer is used for the direct pressure measurement on structural surfaces.可用於結構物表面風壓的量測，同時可用於多個量測頻道。

· Pressure transducers – direct surface pressure measurement using fast sampling transducers.快速表面風壓量測的壓力轉換器

· Environmental measurement – thermo cameras 熱影像儀, vane anemometer 葉片式風速計, thermo-anemometer 熱線式風速計, temperature probes 溫度探針, thermo-hygrometer 溫濕度計, atmospheric pressure sensor 大氣壓力計.

· Five-Hole Probe Aeroprobe 五孔式航空探計– used to obtain the scalar and vector properties of complicated flow fields in terms of three-dimensional velocity component.用於量測 3 維複雜流場的具方向性的風速量測

· Flow Visualization 流場可視化 – fog generator, helium (He) bubble generator system. 高容量液滴產生器，霧發生器，氦（He）氣泡產生器系統

圖 5 捷克 ITAM 風洞內噴水系統

· Manometer LU 200（LU200 壓力計）– vertical liquid column manometer for measuring variations of pressure, depression or differential pressure of air. 垂直液柱壓力計，用於測量空氣壓力，低壓或壓差的變化

· Pitot Tubes（皮托管）– a pressure measurement instrument used to measure air flow velocity. 一種壓力轉換設備，用於量測流場流速。

圖 6 ITAM 風洞實驗室儀控區域

(二) 風洞試驗設備種類介紹

2.1 風洞種類

風洞的種類有許多種，適用的問題也各不相同，以下僅就幾種常見的風洞做一介紹。風洞依其送風方式可分為：(1)吹風式；(2)吸入式。以下分述之：

(1) 吹送式(Blowing type)風洞：

吹風式風洞乃利用風扇將空氣經由整流段、收縮段吹入風洞之試驗段，如圖 11.1 所示。此類風洞的構造較簡單，但其缺點為試驗段之風場會受風扇所產生之螺旋渦流的影響，容易形成二次流，風速分佈較不均勻。

(2) 吸入式(Suction type)風洞：

吸入式風洞將空氣吸入整流段、經過收縮段、進入試驗段，再由風扇口排出。此類風洞氣密性(Air-tight)的要求較高，但試驗段中風速的均勻性及穩定性較吹送式風洞來得好，故許多研究風工程問題的風洞皆屬吸入式風洞。

風洞依其使用目的可分為：(1)航空風洞；(2)環境風洞。以下分述之：

(1) 航空風洞：

此類風洞又稱為高速風洞，其風速可達數倍的音速。此類風洞的試驗段較短，具有均勻風速剖面，低紊流強度的特性，適用於航空氣體動力學之研究。其風洞的試驗段連通至一個密閉的儲氣槽，在試驗之前，利用空氣幫浦將儲氣槽儲滿空氣(吸入式風洞則利用真空幫浦抽成真空)。試驗開始時，將試驗段至儲氣槽的閘門打開，儲氣槽中的高壓氣體一洩而出，在試驗段中形成高速的氣流。但等速的風場無法維持太久，其試驗的時間往往僅數分鐘而已。

(2) 環境風洞：

此類風洞又稱為邊界層風洞，其風速範圍較低，最大風速多在 60 m/s 以內。但其試驗段較長，可在試驗段中形成一個較厚的邊界層流，適用於大氣邊界層流或風工程研究

之用。此類風洞大多藉由風扇的轉動在試驗段中形成穩態的風場，試驗時間可連續數小時之久。

風洞依其構造形式可分為兩種基本類型：(1)閉路循環式；(2)開放式。以下分述之：

(1) 閉路循環式(Closed-circuit type)風洞：

閉路循環式風洞為氣流在一個密閉的管道中循環流動，如圖 11.2 所示。其優點為不受外界風場的影響，適於模擬溫度分層或低紊流強度之流場，能量使用的效率高，可以有兩個試驗段。但其缺點為風洞得占地較大，造價昂貴，易產生二次流，且風扇運轉所產生的熱能不易排出，會造成風洞內溫度逐漸升高，或擴散實驗之追蹤劑的濃度會累積而造成背景濃度逐漸升高等問題。

(2) 開放式(Open type)風洞：

開放式風洞為一個直線的管道中，空氣由一段進入風洞，另一段排出。其優點為占地較小，造價較低，且不會有風洞內溫度或濃度逐漸升高的問題。但缺點為易受外界風場的影響，紊流強度較高，能量使用效率較低(Snyder, 1979)。

2.2 風洞構造

許多研究風工程問題的環境風洞皆屬於開放、吸入式風洞，故在此特將此類風洞的主要構造部分做一介紹。其他種類風洞的基本構在亦極為類似，細節可參考專門書籍(Barlow, et., 1999)。圖 11.3 是一個開放、吸入式風洞的影像圖，圖 11.4 和圖 11.5 為其立體構造圖、上視圖與側視圖，其構造可分為整流段、收縮段、試驗段及動力段。其設計分別說明如下：

(1) 整流段(Flow Conditioner)：

自然界風場極不穩定，因此在進入風洞之後必須加以整流，整流場擾動減至最少，增加流場的穩定性和均勻性。一般而言，風洞的整流段包括有蜂巢管(Honey cone)和細網(Screen)。蜂巢管是由許多正六角形或圓形管整齊排列而成，可將通過得渦流切割成小渦流，減小氣流在流動方向和橫向上的擾動和渦流，亦可使得收縮段較不易產生分離現象，增進氣流均勻性和穩定性。蜂巢管之後便是整流細網，其功能是將通過蜂巢管的

渦流再切成更小的渦流，降低流場的紊流強度，使得通過的氣流成為低紊流強度之流況。一般來說，網目愈細，整流效果愈好，但相對的能量耗損也愈大。

(2) 收縮段(Contraction)：

收縮段的目的在於藉通風斷面得縮小，使得通過之氣流加速。較大的收縮比(Contraction ratio)可使的風洞內有較大的風速，但收縮段長度和斷面亦需要按比例增大，風洞造價與所站的空間也就需要增加。較小的收縮比則風洞內風速較小，且容易產生分離現象。風洞之收縮段大多為多項試曲線相接而成，良好的收縮段可進一步地抑制紊流擾動，並在試驗段內形成接近均勻的流場。

(3) 試驗段(Test section)：

試驗段為風洞試驗進行之處，斷面大多為矩形，亦有圓形及八角形。試驗段的尺寸與模型的大小有密切的關係。若模型之阻塞比(Blockage ratio)(模型之迎風面積與風洞斷面積之比值)過大時，氣流會因為通風斷面的縮小而產生加速現象，導致風速之量測結果有誤差。一般而言，模型之阻塞比應小於 5%，若阻塞比大於 10%，應調整風洞試驗段上壁的高度，或對試驗結果做適當的修正。因此採用較大尺寸的模型時，試驗段之斷面亦需要很大，但這會增加整個風洞的尺寸、所需馬力和造價。反之，若採用較小的模型，則縮尺效應(Scale effect)會造成試驗結果失真。

因為地表附近的大氣邊界層厚度較一般建築物高出許多，為使建築物之模型尺寸在合理範圍內，風洞中之邊界層厚度亦需要相當大。且風洞之試驗段需要有足夠的長度，以供風洞發展出夠後的邊界層。依據 Cermak (1984)之建議：邊界層風洞的試驗段長度應屆於 10 ~ 20δ，寬度應在 2 ~ 4δ，δ為邊界層的厚度。譬如都會地區的大氣邊界厚度約為 400 m，若以 1/400 的比例縮尺製作模型，則風洞中的邊界層厚度為 1.0m，亦即試驗段的長度起碼要有 10 ~ 20 m，高度必須大於 2.0 m，寬度約為 2.0 ~ 4.0 m。

試驗段之上壁應可調整其高度，以便於調整風洞中的縱向壓力梯度。在試驗段內應設置試驗轉盤，以改變對模型之有效風向。試驗段內部可設置三度空間活動之天車，由風洞外遙控量測探針之位置。另外可在試驗段上壁設置照明設備，左右側壁及上臂設置大型透明窗，於以便於直接觀測風洞中的流況。

(4) 動力段：

動力段包括收縮管(Contraction tube)、風扇(Fan)及出口擴散管(Diffuser)。收縮管將矩形之試驗段轉變為圓形之風散進口，其直徑應與試驗段尺寸相近。風扇以馬達驅動，風扇葉片的角度最好可以調整以微調風速，最高風速最好可 20 m/s 以上，風扇馬達之馬力應以最高風速來設計。試驗段和風扇之間應設置一個安全網(Safety screen)，以避免吹落的物體打壞風扇葉片。動力段最好有一個獨立的地基，且動力段與試驗段接縫處應以軟性帆布相連，以避免馬達及風扇轉動所引起的振動傳遞到試驗段，影響試驗的結果。出口擴散管形狀多為圓形之喇叭口，氣流由此排出。

(三) 環境風洞實驗室（Climatic Wind Engineering Laboratory）參觀

捷克科學研究院理論與應用力學所（ITAM）之環境風洞實驗室係由 Stanislav Pospisil 教授所設計並主持，實驗室位於捷克泰爾奇(Telc)，為捷克科學研究院理論與應用力學所（ITAM）泰爾奇卓越中心(The Centre of Excellence Telc,CET)的實驗室之一。距離布拉格約 50 公里，參訪當由 Stanislav Pospisil 教授親自駕車載一行人由布拉格前往實驗室參觀。到達風洞實驗室時由 Arsenii Trush 主任導覽實驗室，Arsenii Trush 目前係由捷克理工大學土木工程學系博士候選人。

Arsenii Trush 說明泰爾奇卓越中心(The Centre of Excellence Telc,CET)配置獨特的設備用以執行土木結構與材料基礎研究並驗證構造診斷、增加生命週期和古蹟的維護與保存等領域科技的創新與應用。CET 係由數個實驗室組成，其中之一為環境風洞實驗室，該實驗室係以環境和經濟最佳化為設計原則，設置有實場量測與商業檢測設備以執行氣動力及流場可視化試驗。

環境風洞試驗主要以模型模擬主要建物及其週遭附近環境，包括天氣的循環變化與下雨量，以量測結構受風載重。甚至可進一步透過長期監測和模擬，以了解實際結構物曝露在長期天候下易受影響的變數或長期反覆疲勞之損壞等，同時亦可經由適當的縮尺模型，提出良好方案以確保更舒適的建築環境。

此風洞實驗室具有 2 個測試段，一為氣動力試驗測試段，另一為環境測試段。本次參訪發現，氣動力試驗測試段之功能屬性及特色方面為典型的風洞試驗設備，可執行各種構造物之氣動與氣彈模型試驗，但橫斷面尺寸僅為 1.9×1.8 m，只能執行局部斷面之橋梁模型試驗，全橋試驗則顯不足。個人認為此實驗室最大特色為環境測試段，在風洞內除了提供風場，亦可加入其他氣候條件如雨水、太陽輻射等功能，藉以模擬構造物在實際天候條件下的受力或材料特性變化情形。在氣動力測試段執行建築物風載重或表面風

壓模擬時，一般僅考慮風場的影響。在環境測試段內可增加雨水對建築物風載重或表面風壓影響的研究，以瞭解在颱風時，風雨交加的氣候條件下，建築物表面或門窗所需之耐風強度。另外據 Stanislav Pospisil 教授和 Arsenii Trush 主任表示，該環境測試段目前主要用在捷克古蹟保護研究，捷克首都布拉格市區內的建築構造多為混凝土加強磚造構造，古蹟城牆眾多。因此，環境測試段內，可透過雨水和溫度的變化調節，瞭解古蹟城牆內濕度變化，進一步探討其強度變化機理。

ITAM 風洞實驗室為近年興建完成之實驗室，不論人力配置或經費運用上尚未完全到位，在實驗室的營運管理方面，目前僅研究員 1-2 名常駐實驗室負責營運管理和設備維護或試驗規劃等事宜，如需執行試驗缺乏之力則從其他地方調派人力支援。經費來源方面，主要仰賴政府預算占支出 70%，另有 20%由研究計畫支出，及 10%檢測業務支出。

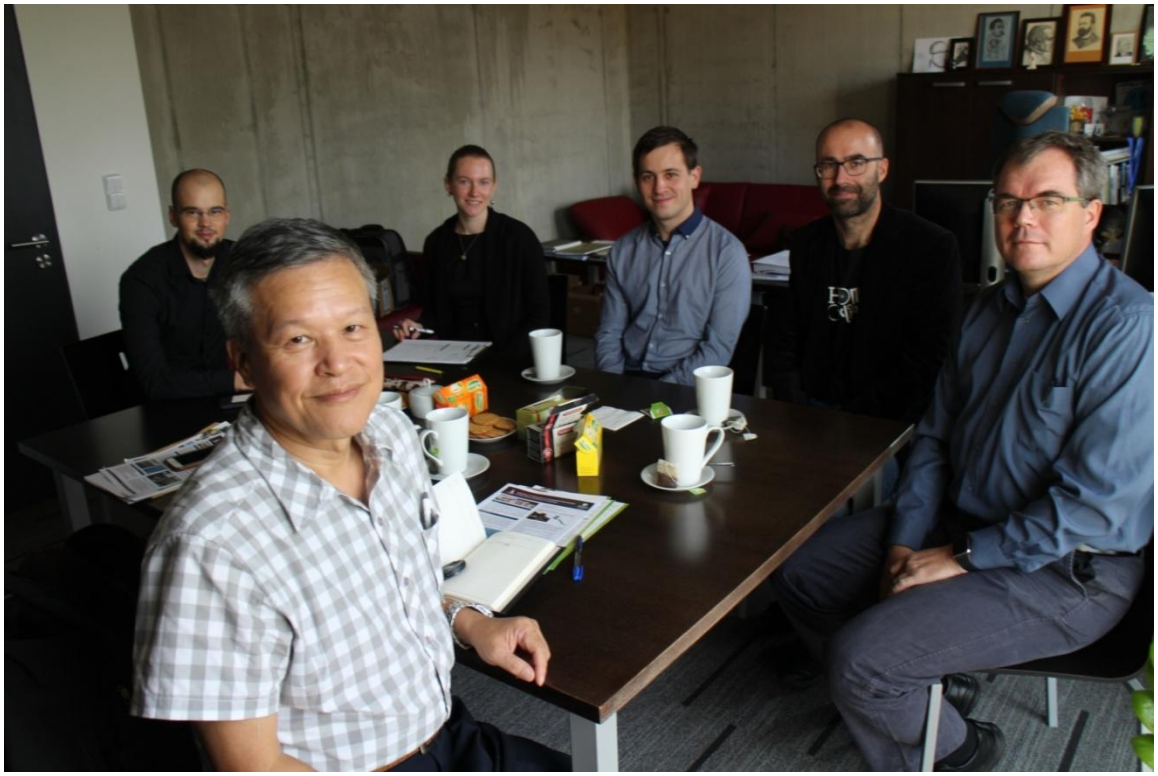


圖 7 與捷克 ITAM 風洞實驗室 Stanislav Pospisil 教授等人合影

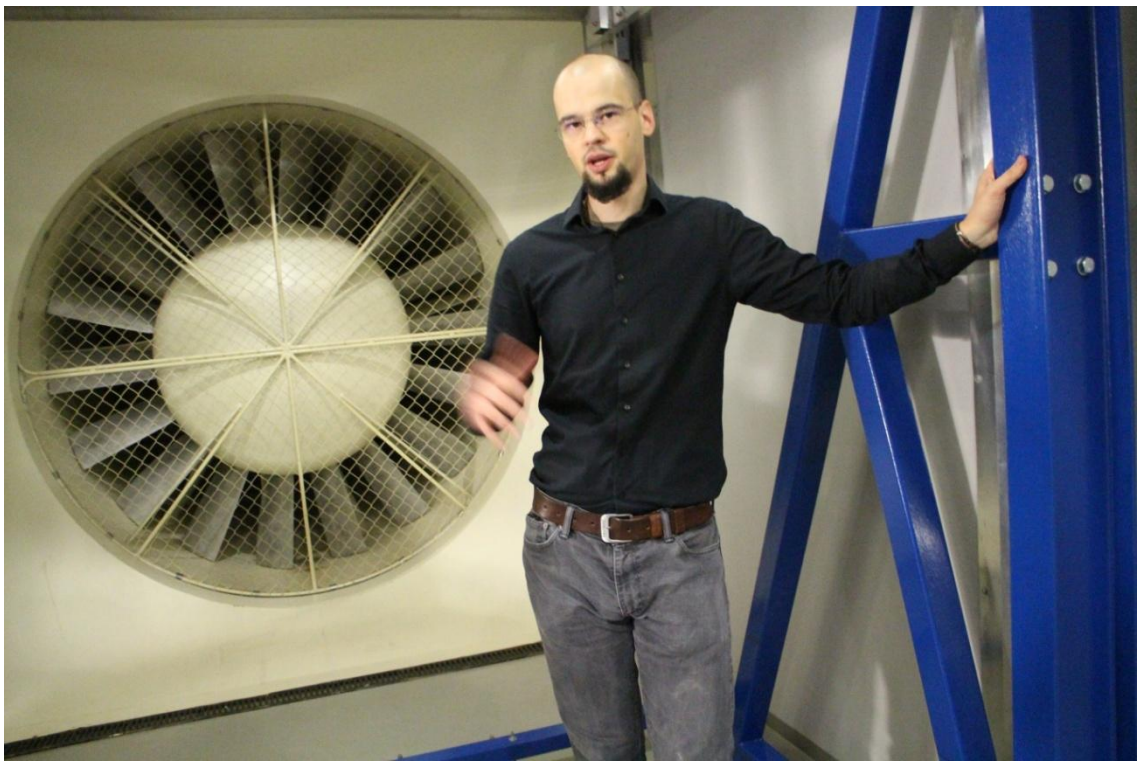


圖 8 實驗室 Arsenii Trush 主任介紹風洞設備

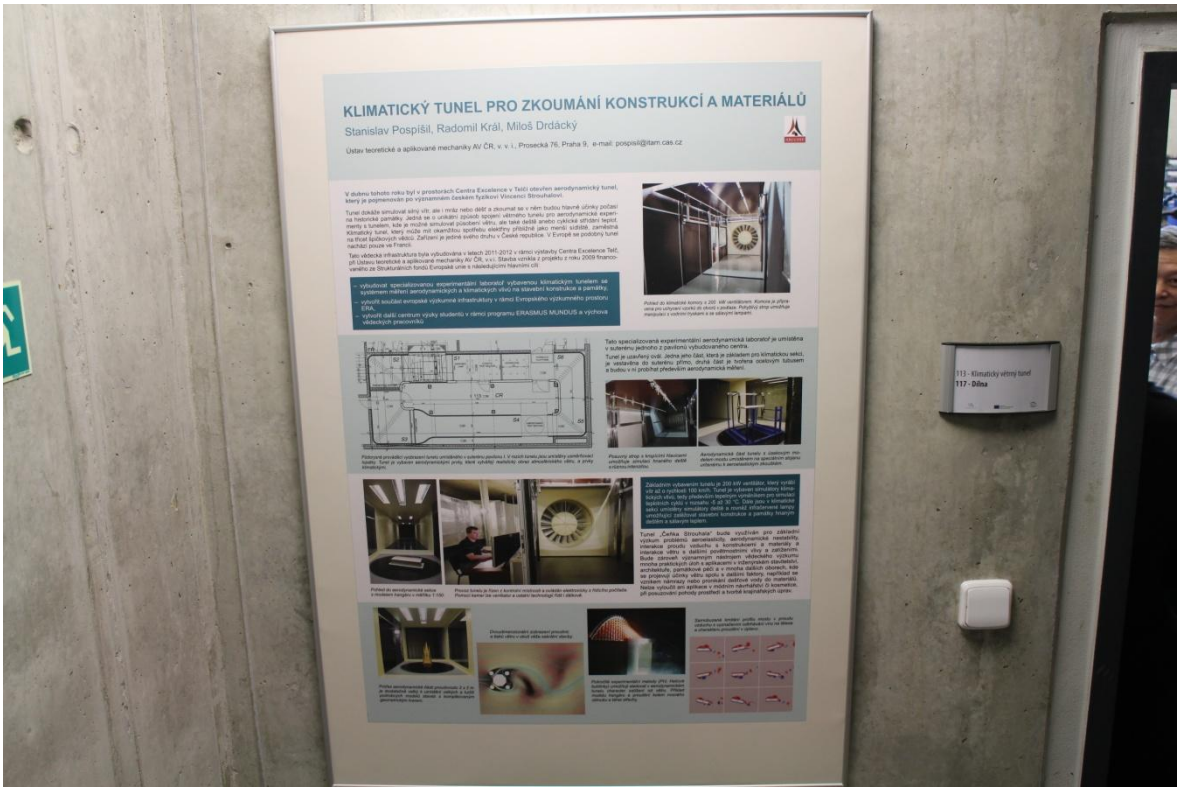


圖 9 捷克 ITAM 風洞實驗室介紹海報

圖 10 捷克 ITAM 風洞實驗室環境測試段內噴水系統

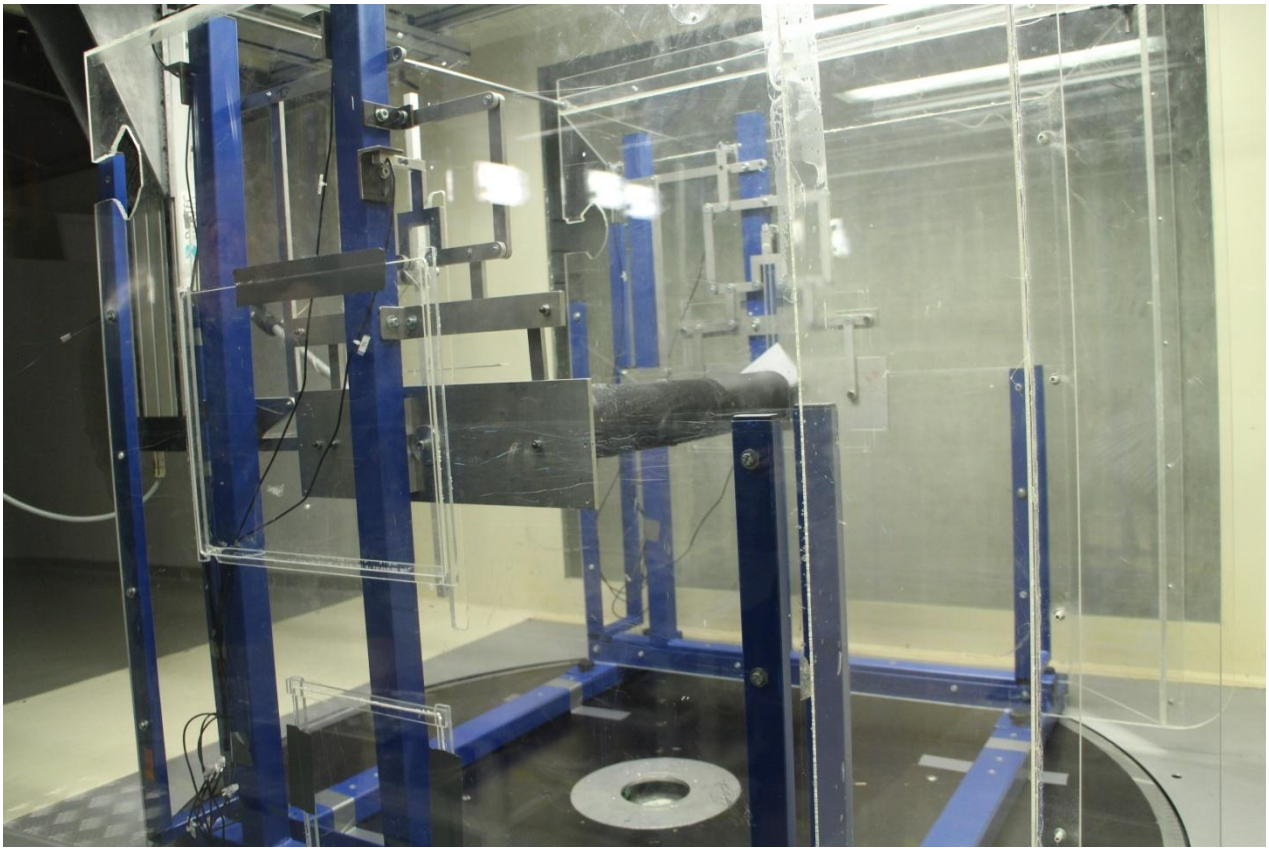


圖 11 捷克 ITAM 風洞實驗室內橋樑斷面測試

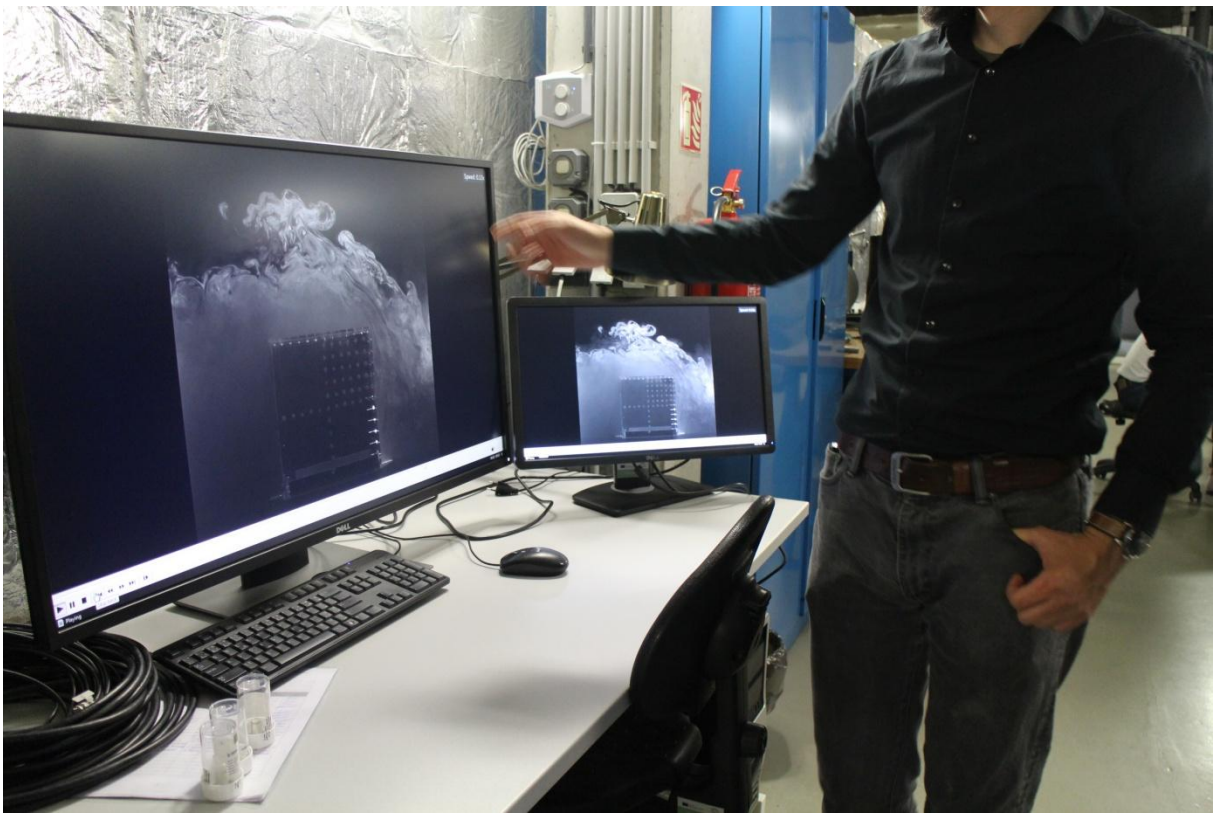


圖 12 Arsenii Trush 主任介紹流場可化情形

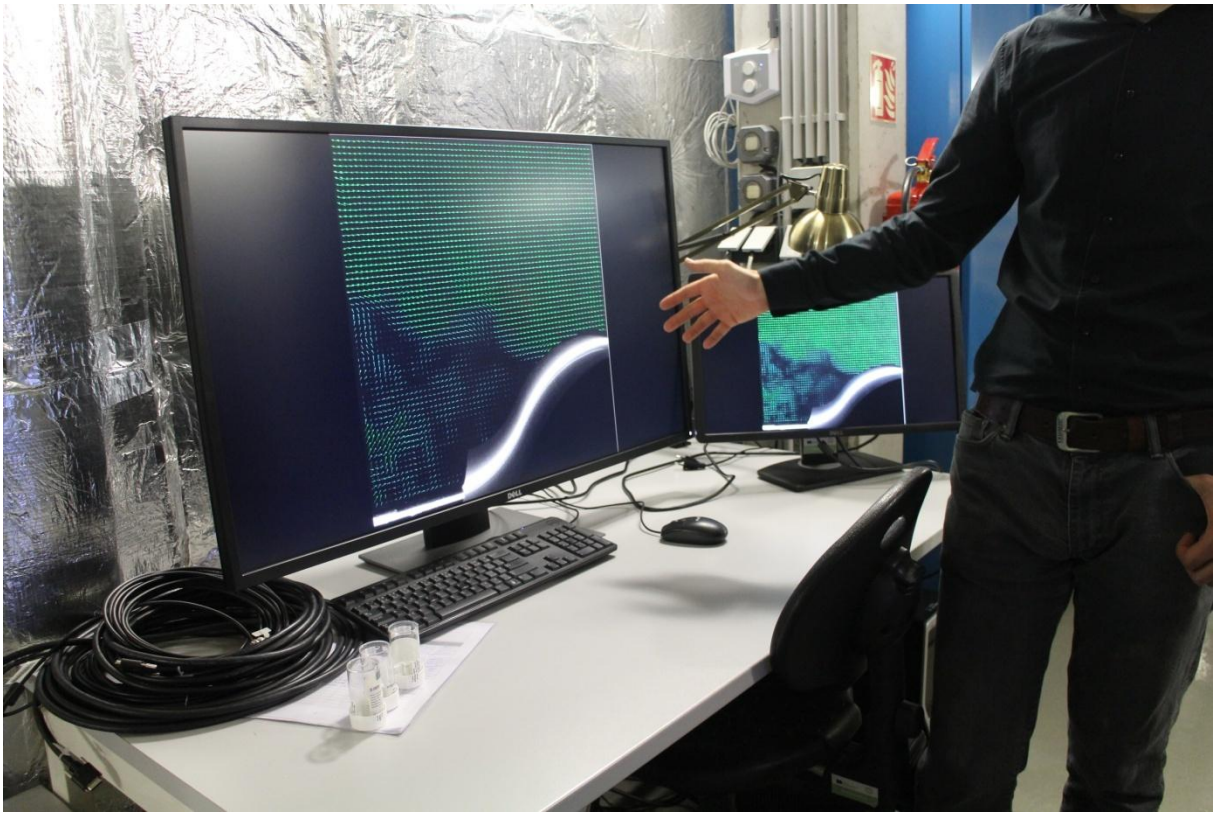


圖 13 Arsenii Trush 主任介紹 PIV 風場流線成果顯示

圖 14 Arsenii Trush 主任介紹氦（He）氣泡產生器系統

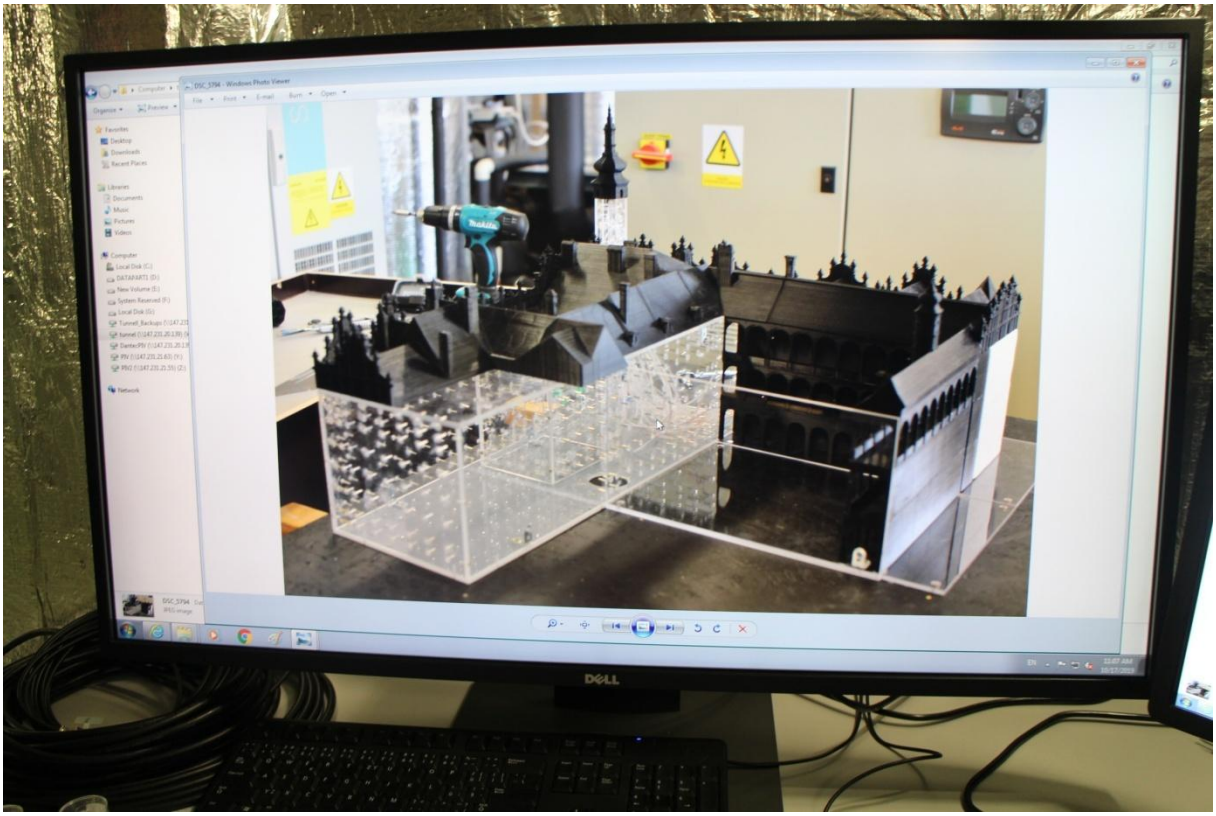


圖 15 風洞實驗室建置古蹟模型量測牆體表面風壓

圖 16 風洞實驗室磚牆試體

圖 17 磚牆試體內埋設溫濕度量測計

二、參觀捷克 UCEEB 實驗室

UCEEB 是捷克技術大學在布拉格成立的獨立機構，由土木工程，機械工程，電氣工程和生物醫學工程四個部門主持。 中心的目標是利用各個部門與節能建築相關的研究活動的協同效應。

UCEEB 是對歐盟旨在優化建築節能的最大優先事項之一的回應。 新的中心還應該有更好的機會參與歐洲的科學項目，例如基於歐盟二氧化碳排放目標的“節能建築聯合技術倡議”。顯然，可持續建築不僅是一種趨勢或時尚，而且是必不可少的。 這就是為什麼我們從整體上看待節能建築的原因。

主要研究5個研究團隊：Architecture and the environment、Energy systems in buildings、Quality of indoor environment、Materials and structures、Control and monitoring of intelligent buildings。本次主要參訪 Quality of indoor environment 團隊，我們致力於為節能建築的用戶提供室內氣候的質量（健康，安全和舒適）。

我們的方法是多學科的，包括三個主要領域：開發和設計用於提供高質量室內氣候的先進技術設備、監測智能建築中生物和技術參數的醫療輔助系統的研究與開發、研發用於醫學和技術應用的智能複合納米系統和材料（有害物質檢測，室內氣候監測等）

並行測試室，用於在外部環境受控的情況下測試建築技術系統、具有太陽能煙囪的混合通風系統、小型空氣處理機組和部件的測試線、帶個人醫療系統的智能室、具有抗黴菌和抗菌特性的納米材料研究與開發實驗室、電動和力微調器、人體熱感應模型、計量和監測熱舒適度以及空氣質量分析的儀器、PIV-粒子圖像測速、用於 CFD 模擬的計算機集群。

Laboratory of Indoor Environment – Dual Climatic Cabin 該實驗室的重點是內部環境領域的發展，尤其是熱感和建築物的空氣品質。實驗在雙氣候艙中進行。 這些用於通過各種加熱，冷卻和通風設備分析環境。 目的是改善這些設備的特性，以提高環境質量並改善能源的利用。雙氣候試艙具有兩個彼此相鄰的相同房間的形式，每個房間的尺寸為 4.4 x 3.1 m，高度為 2.85 m。 它處於受控的外部環境中，溫度範圍為 – 15°C 至+35 °C。

圖 18 雙氣候試艙

實驗室主要工作與活動：

- 對熱環境及其人員感知的實驗室分析
- 使用激光風速測定法對流體流動進行實驗室分析
- 通過使用移動設備進行測量並進行評估，來全面分析實際運營中的內部環境（熱舒適度，空氣質量，照明，聲學，電離環境）
- 用戶對環境的主觀感知
- 優化系統的運行參數以保護環境
- 開發和測試用於室內供暖，製冷和通風的新設備

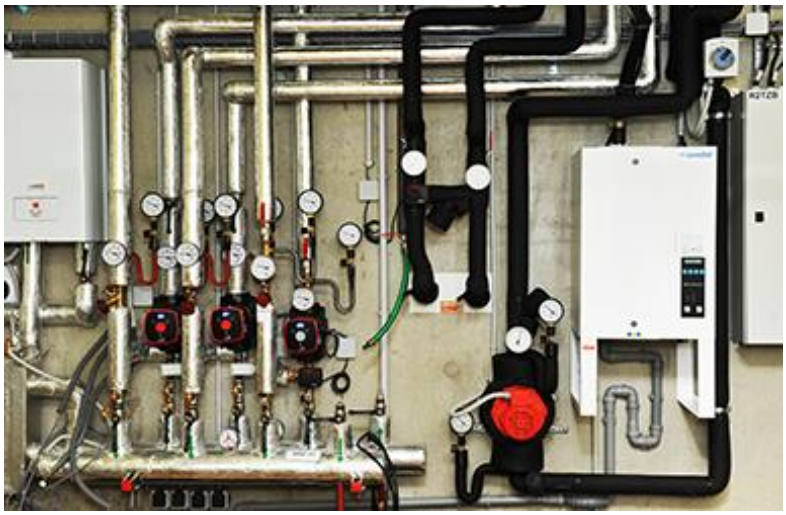


圖 19 空調冷暖氣交換則試

儀器設備

- Thermal mannequin 熱感應人體模型 – a model of human body simulating its response to the surrounding thermal environment.人體模型用於模擬對於附近熱環境的反應
- Laser anemometry – a system for analyzing the air flow in the room based on the captu ring of the movement of particles carried by the air. 一個基於捕獲空氣中顆粒運動的系統來分析室內空氣流動的系統。
- Analyzers of air quality – a set of devices for measuring the concentration of common gaseous noxious agents and dust and for taking samples 一套用於測量常見氣態有害物質和粉塵濃度並取樣的裝置

圖 20 PIV 可視化設備

圖 21 UCEEB 建築外觀

圖 22 UCEEB 大廳

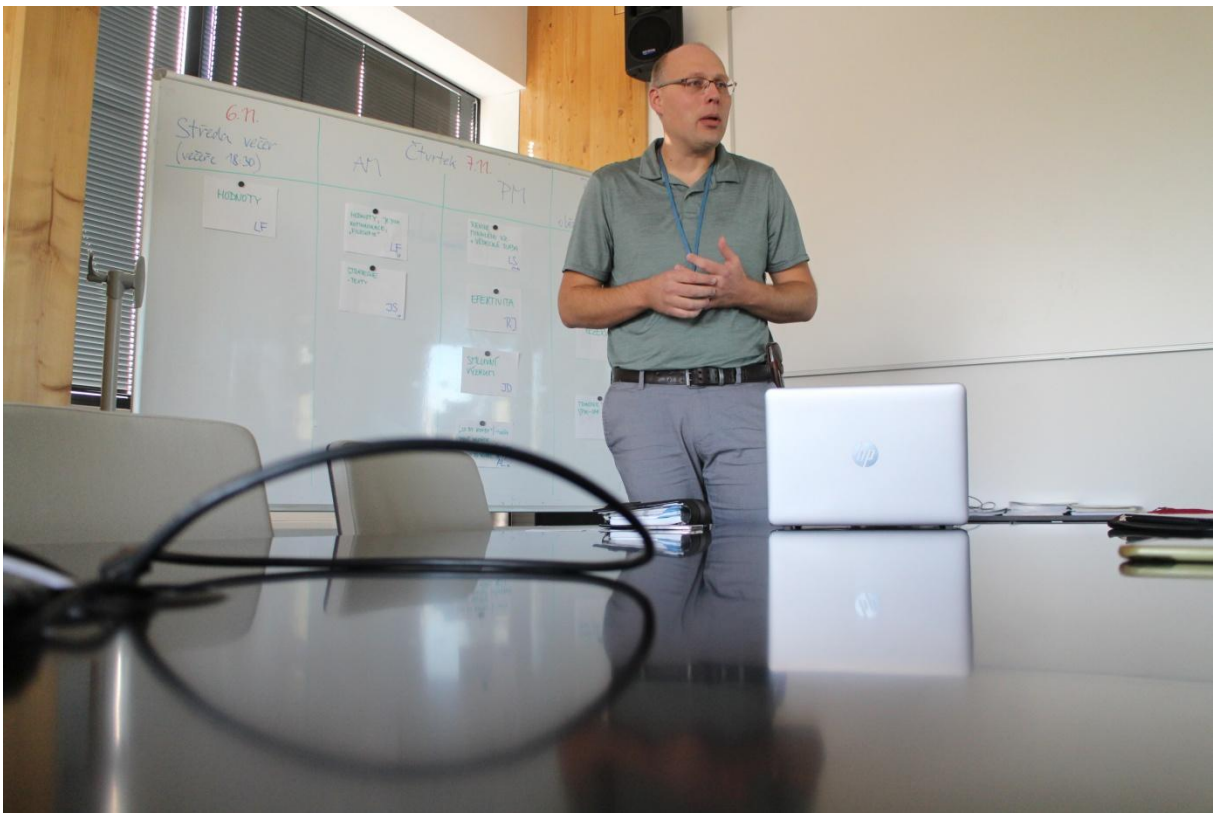


圖 23 Daniel Adamovsky 博士簡報情形

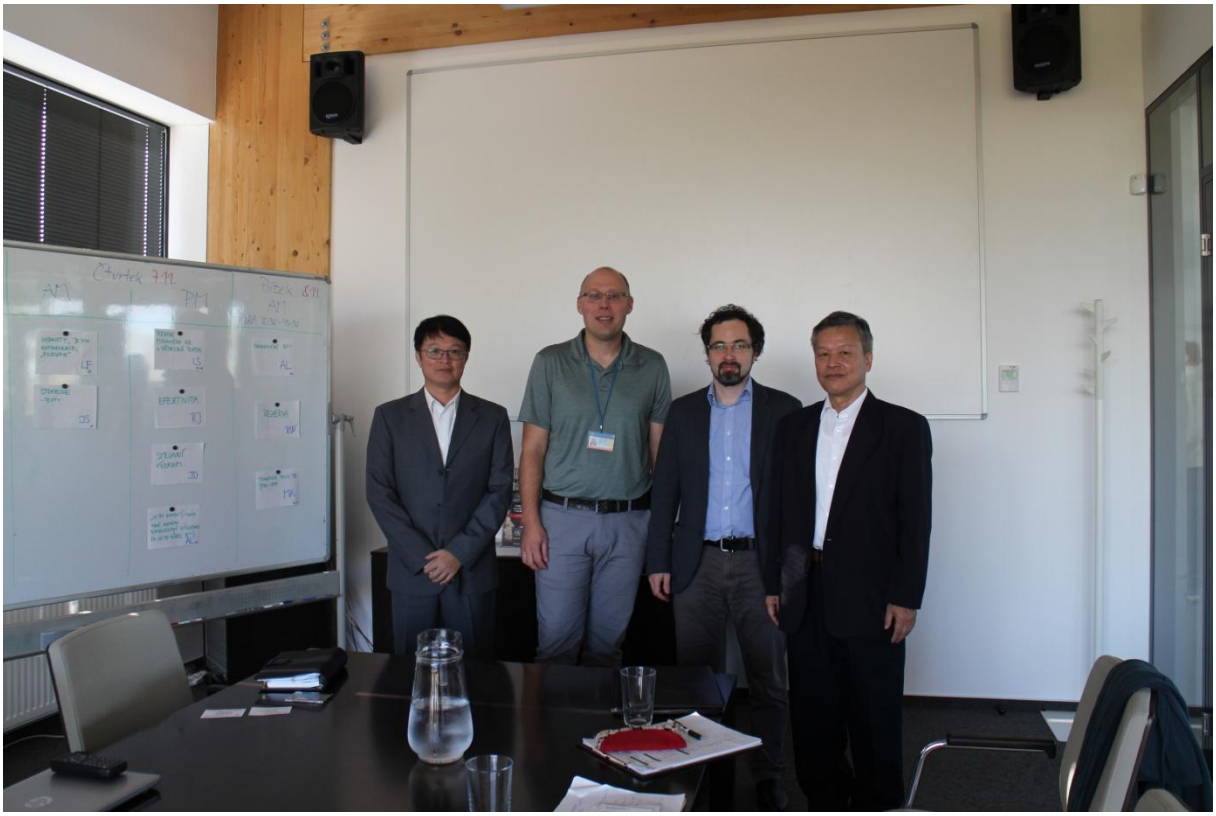


圖 24 與 Daniel Adamovsky 等人合影

圖 25 UCEEB 鋼構試驗場

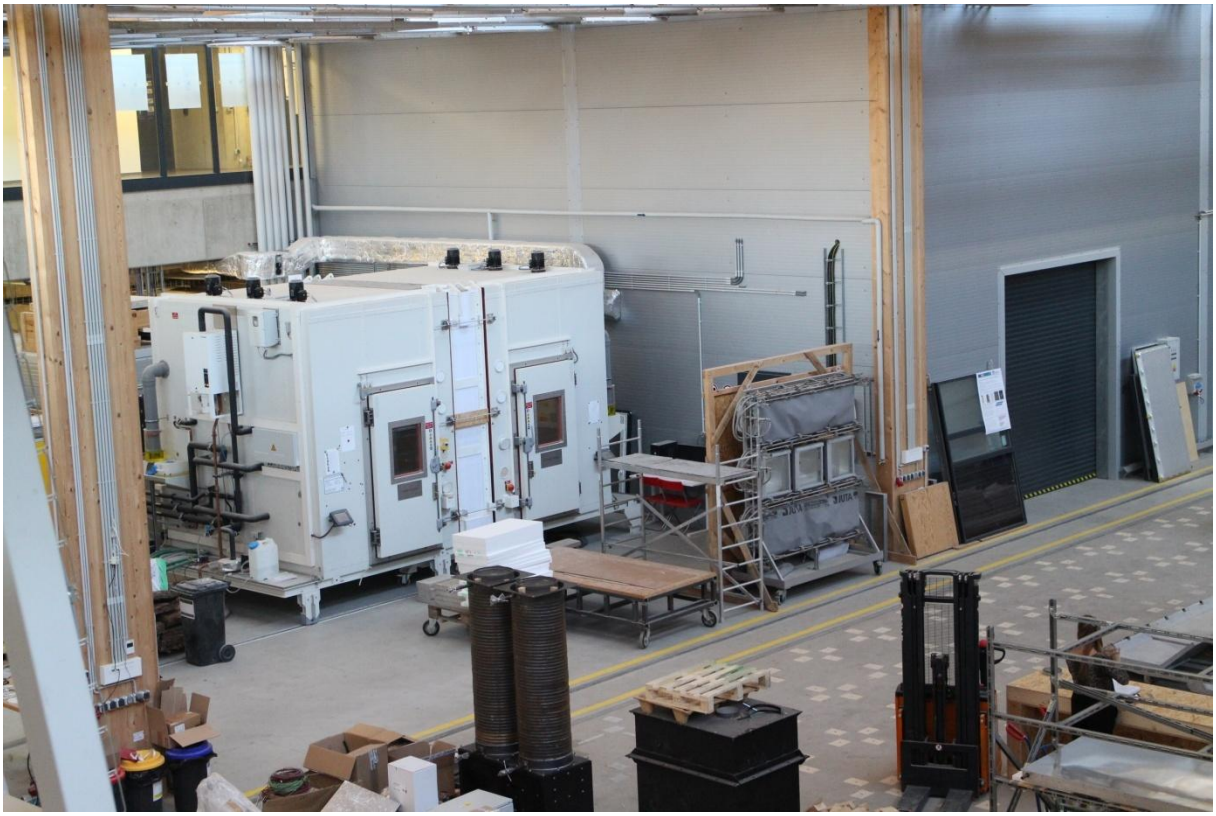


圖 26 UCEEB 試驗艙

圖 27 人體模型熱感試驗

圖 28 UCEEB 能源效能試驗

圖 29 Daniel Adamovsky 博士導覽試艙情形

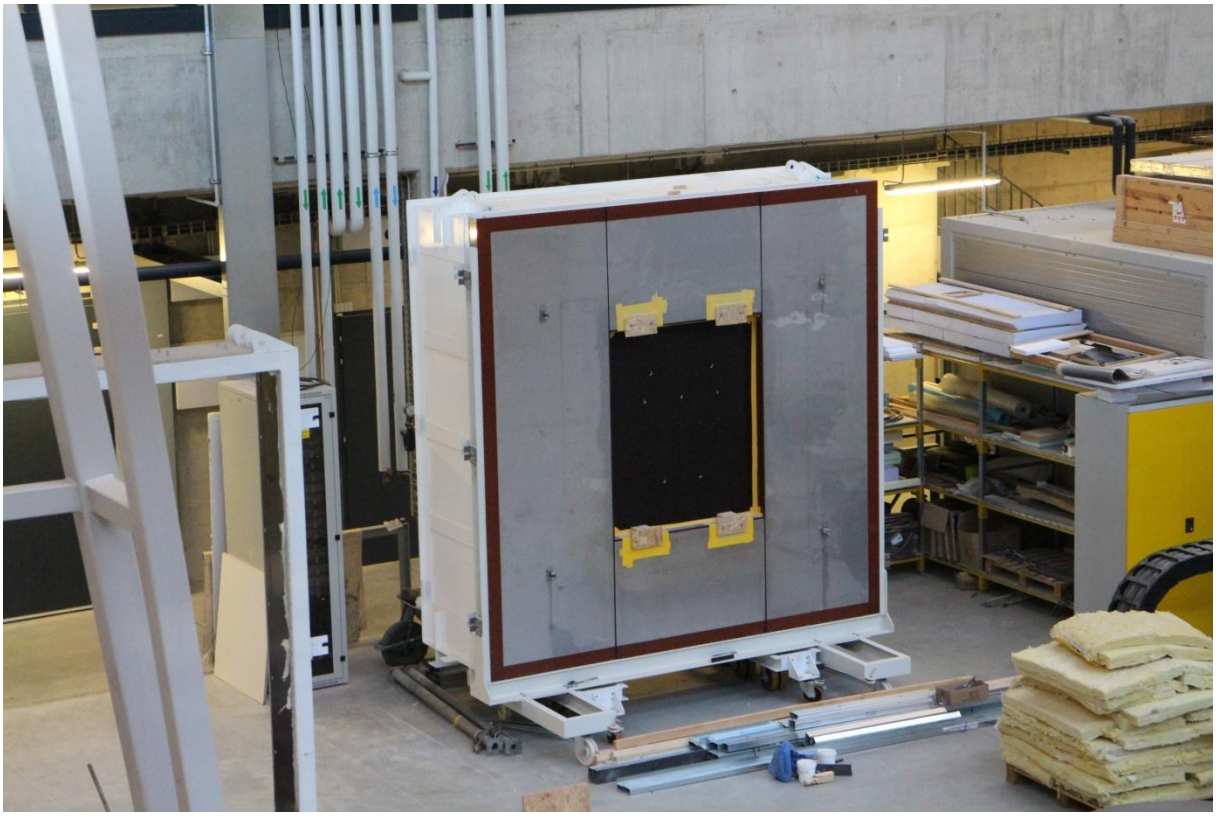


圖 30 UCEEB 測試艙

三、拜訪捷克理工大學土木工程學院室內環境與建築工程設備系

捷克理工大學土木工程學院室內環境與建築工程設備系（Czech Technical University in Prague (CTU), Faculty of Civil Engineering, Department of Indoor Environmental and Building Services Engineering,），由副主任 prof. Michal Kabrhel 接待導覽。.該系成立於 1960 年，屬於捷克理工大學土木工程學院系所之一。而捷克理工大學為歐洲最古老的理工大學之一。建築技術設備包括衛生設施，建築物的供暖和製冷，空調，電線，建築技術，人造照明，計算機建模，室內環境理論和能源性能等領域的系統的設計、實施和系統操作。該系成立宗旨為建築科技設備領域研究與發展、符合資料的大學生、碩博士的研究教育訓練、研究與教育計畫的國際合作、標準與規範合作、政府部門與專業組織合作與終身學習等。

參訪當日副主任 prof. Michal Kabrhel，除就該系發展作簡略介紹外，導覽智慧建築實驗室與建築服務示範和教育實驗室。智慧建築實驗室旨在創建技術設施，以實施實驗和驗證配備智能係統的現代建築中使用的技術。 該實驗室還用於支持學士，碩士學位和博士學位課程的教學。在實驗室中，有執行器，傳感器，控制器和通信技術的演示面板，在其上安裝了有源和無源元件，以演示技術系統的操作。實驗室分為多個工作區，重點關注智能建築系統各個部分的問題。工作區的一部分是位於建築物外部的氣象站，該氣象站不斷在此位置捕獲氣象數據。試驗工作區使用智慧光源，它設計用於測試和分析選定類型的燈具以及測試測試室內部環境的選定參數。 駕駛室照明系統可以通過計算機技術控制。試艙是一個自主的實驗室空間，可以創建不同的照明條件。工作區具有建築物能源管理最化模擬，它配備了強大的計算機技術和仿真程序。 在這裡可以模擬整個建築物以及建築物或系統的一部分的運行。智能通風控制分析套件，它包含主動和被動元件，設計用於從通風的房間供氣，調節和排出空氣， 這些元素亦可在實驗室外使用。

建築服務示範和教育實驗室：示範和教育實驗室位於布拉格捷克技術大學的土木工程學院。 實驗室是為教育目的而設立，主要是博士和博士課程，具體包括：建築與環境、智慧化建築、建築構造及建築設計。實驗室的基本部分是配備有熱控制內表面和可調節氣流入口和出口的測量艙。 試艙尺寸為深度 3 m，寬度 3.5 m，高度 2.9 m。 機艙結構是內置於實驗室的輕型隔熱結構。 內表麵包含毛細管墊，上面覆蓋著薄薄的石膏和抗濕氣和水蒸氣凝結的油膜。 試艙孤立的混凝土基礎上的地板休息。

每個機艙表面的毛細管墊通過單獨的迴路連接至加熱和冷卻分配器，因此它們各自

可以獨立加熱或冷卻表面。 所有機艙表面的加熱和冷卻輸出在 6 至 8 kW 之間變化。而水力平衡線用於學生學習和實踐水加熱或冷卻系統的穩定性。 該生產線由四個不同的分支組成，代表典型設備的連接。第一分支包括通過三種不同的閥連接的三種類型的散熱器。 緊隨其後的兩個分支表示空氣處理單元中加熱器或冷卻器的兩個變體。 最後一個涉及風機盤管模型。

在測量室中使用的測量裝置適用於空間中的氣流分析以及通風口的氣流範圍測量。佈置包括用於各種空氣速度的速度傳感器，表面和空氣溫度傳感器。 數據在 Ahlborn Almemo 數據記錄器中收集。

儲存箱是由鋼板製成的矩形槽，平面尺寸為 600 x 700 mm，高度為 1650 mm。水箱體積為 690 升。外表面是隔熱的。儲存箱前壁由透明玻璃面板製成。通過外部交換器將提供提供給水箱，以加熱流向水箱入口的水，並模擬太陽能電池板的轉化獲取。該入口歧管管擴散器，該歧管可進入箱體溫度與溫度相似的特定溫度層。最高供水溫度可能達到 70°C，入口流量約為 1 至 18 l / min。可以通過七個單獨的出口從儲存箱中抽出能量，這些出口按儲存箱高度劃分。每個出口都放置熱傳感器 Pt100 和流量計。為了測量目的，第二外部板式熱交換器散發數值。來自出口的冷卻水模擬加熱系統的回流，並連接到第二個內置分段歧管擴散器。出口流量範圍為 1 至 10 l / min。儲存箱有 10 個熱傳感器，安裝在 150 mm 的距離內。傳感器測量儲罐中的垂直溫度場。所有數據均由記錄儀 Ahlborn Almemo 5690 擷取。

熱源是裝有功率 16 kW 的電鍋爐。該鍋爐連接到主熱分配器，從該主熱分配器提供其他熱需求系統。作為冷卻源的是水對水熱泵，可提供 11 kW 的冷卻輸出。 該熱泵在蒸發器側連接到主冷分配器，從該主冷分配器提供其他冷需求系統。 冷凝器側的熱量浪費在室外乾燥機上。

可控制的進出測量室的空氣供應和排氣提供了新型的空氣處理單元，其設計流量為 900 m^3 / h。 該單元根據外部管道的壓降平穩地調節空氣流量。 空氣處理機組配備有換熱熱交換器，空氣冷卻器和空氣加熱器。

冷熱分配系統包括兩個單獨的主分配器和兩個僅屬於測量艙的劣等分配器。 所有管道均由通過壓接安裝在一起的銅管製成。 加熱和冷卻管，閥門和分配器均覆蓋有隔熱層和表面保護膜。

圖31 Michal Kabrhel教授說明參訪行程

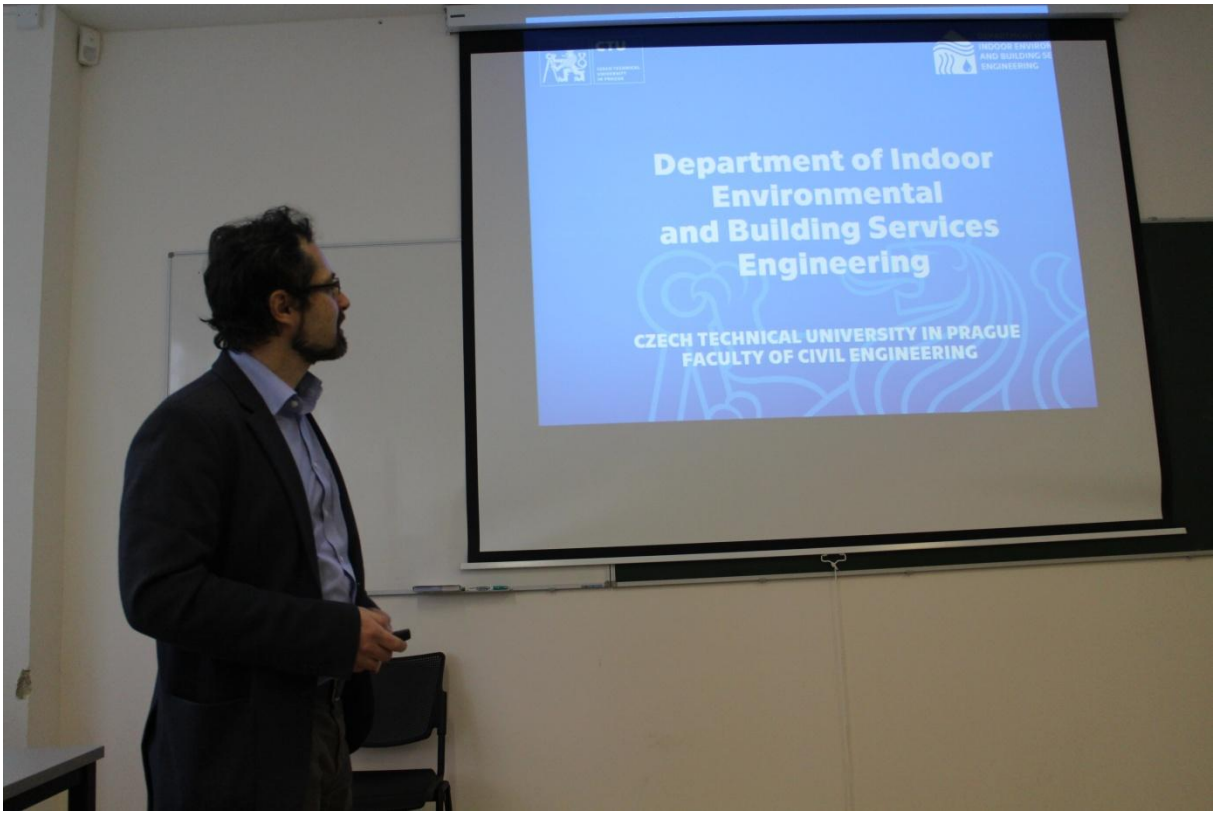


圖 32 Michal Kabrhel 教授簡報情形

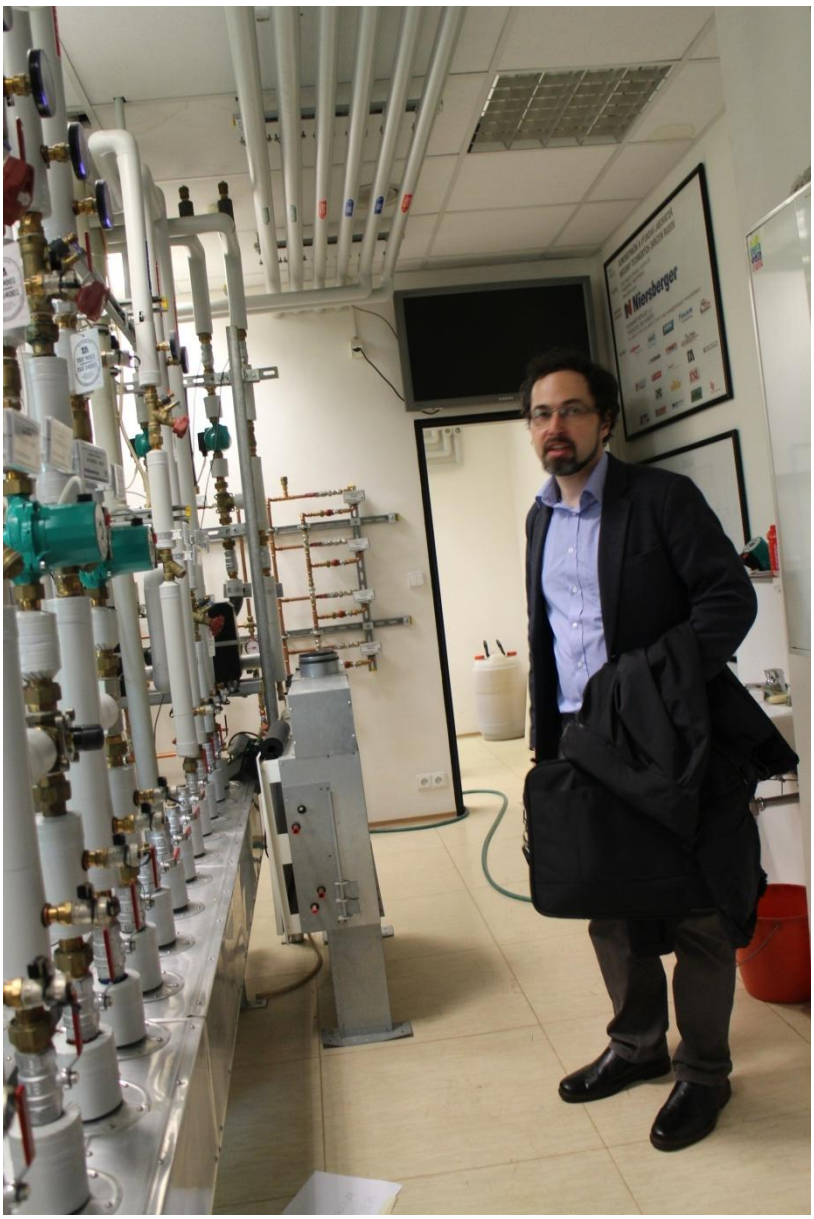


圖 33 Michal Kabrhel 教授導覽該系設備

四、參觀義大利米蘭(Politecnico)理工大學的 GVPM 風洞實驗室

(一)GVPM 風洞實驗室介紹

GVPM 是一個特殊的封閉迴路風洞，具有上下兩個垂直配置的測試段。第一測試段位於迴路低層適用於低紊流測試。第二個測試段斷面較大，位於迴路的上層被規劃用於土木工程測試(大氣邊界層測試段)。由於獨特持性，GVPM 提供最大寬度可能範圍的空間規劃與替換性。風洞內造風設備是由 14 個小風機組成，每個小風機具直徑 1.8 公尺葉片及 100KW 功率，總共可達 1.4 MW 的動能。所有的小風機初配置成兩排，每排有 7 個 2x2m 的獨立單元，每個風機由獨立的變頻器驅動，使其可以控制風速變化，以達到整個測試段內的需求速度。

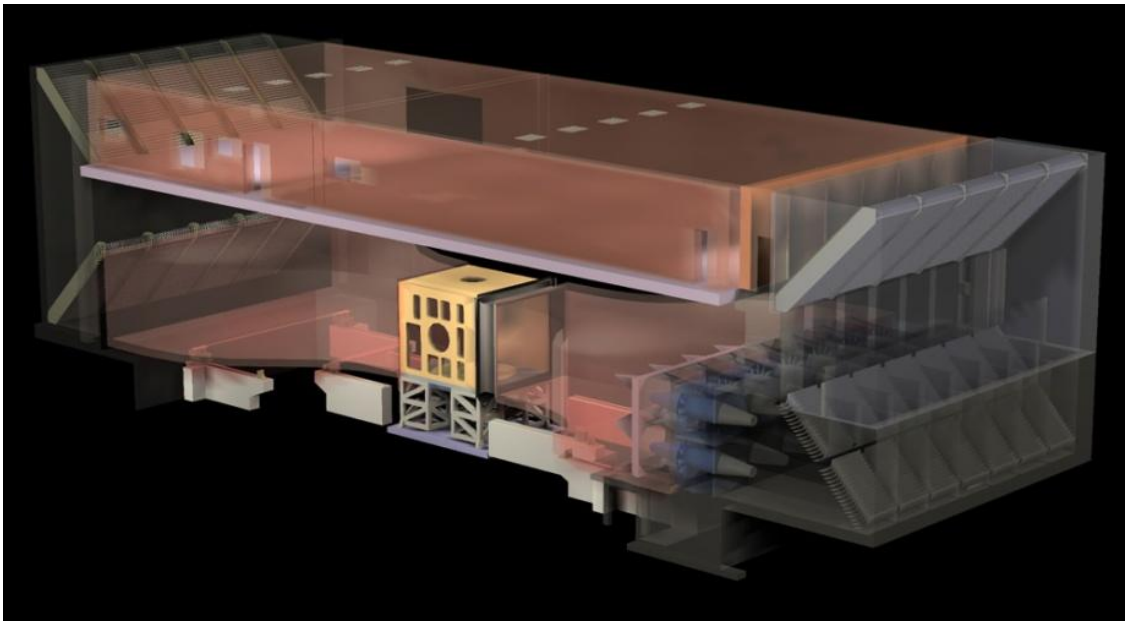


圖 34 GVPM 風洞 3D 立體圖型

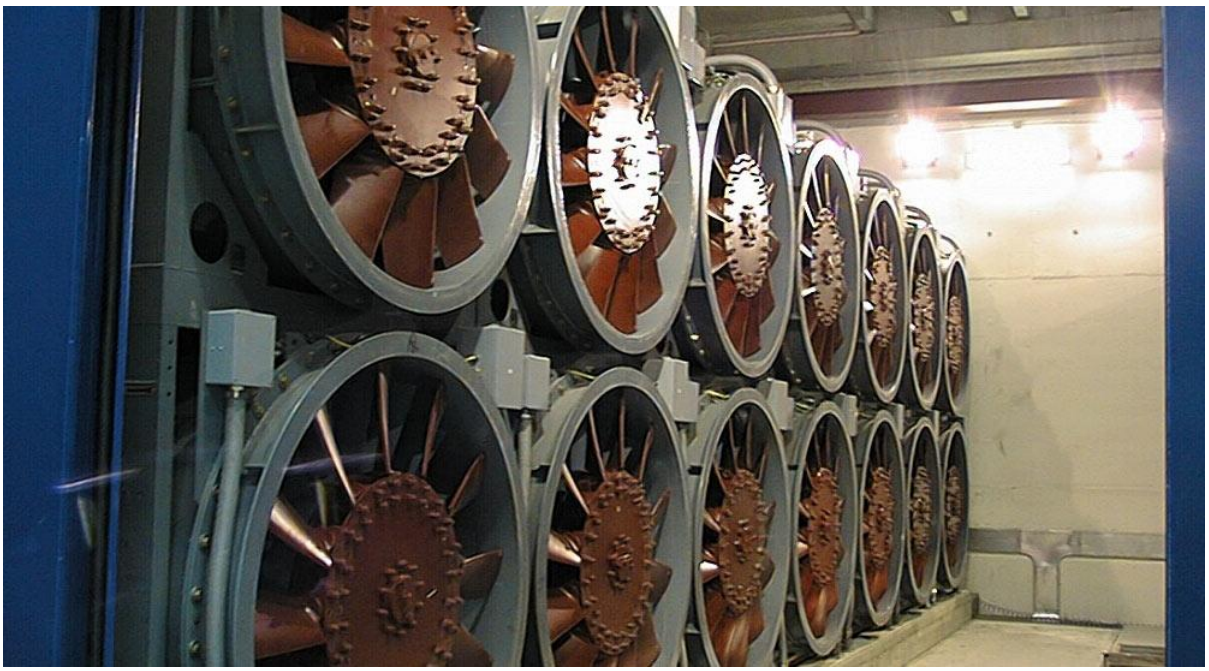


圖 35 GVPM 風洞 14 台風機

在風機的後方兩角落處設有兩個導流葉片，讓流場可以往上層測試段移動，且在流場下游轉彎處設有熱交換機冷卻風場溫度，緊接著流場經一串格柵，將流場整流後進入大氣邊界層測試段。

流場經過大氣邊界層測試段後，下游兩角落處設有第 2 組導風葉片，讓流場回到下層測試段，之後流場會經過一個 2 公尺的試艙，接著通過一個蜂巢網和 3 組不同大小的整流網，以減少軸向和側向紊流，達到低紊流的均勻流場。上方測試段和下方測試段之斷面尺寸不同，兩個斷面的過渡區採用一個面積比 3.46:1 的二維錐體將其連接。之後再以一個較短的擴增段讓流場回到風機處，再往上方測試段循環。

為了將風洞設備配置束組件設計最佳化和查驗，實驗室製作一個 1:9 的等比例風洞縮尺模型，該模型經過多次修改達到最終設計，此模型目前可運作用來查驗修正全比例風洞之特性，並於在執行大風洞試驗前先在小風洞設計測試元件或試體模型。

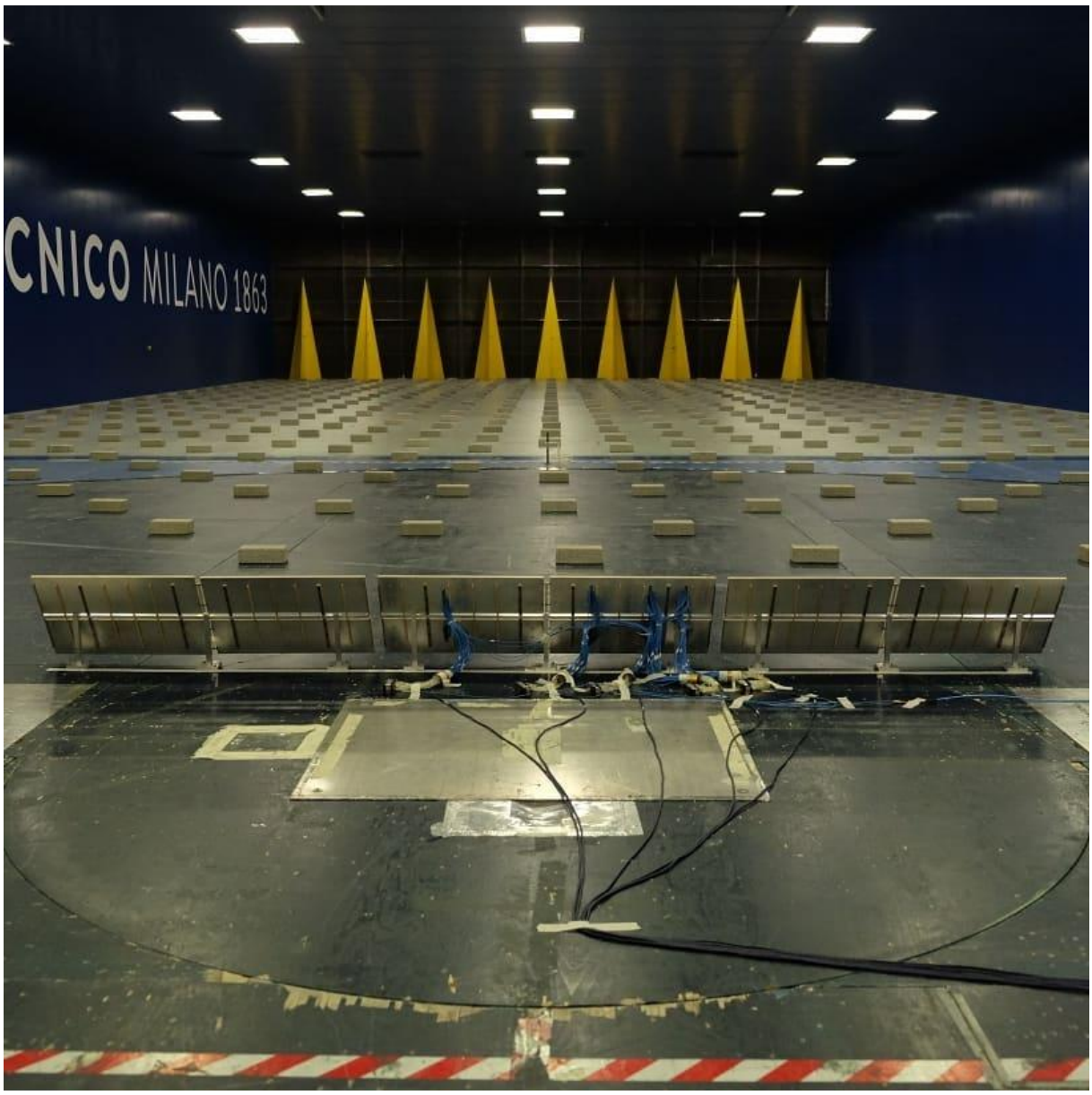


圖 36 GVPM 大氣邊界層地況模擬

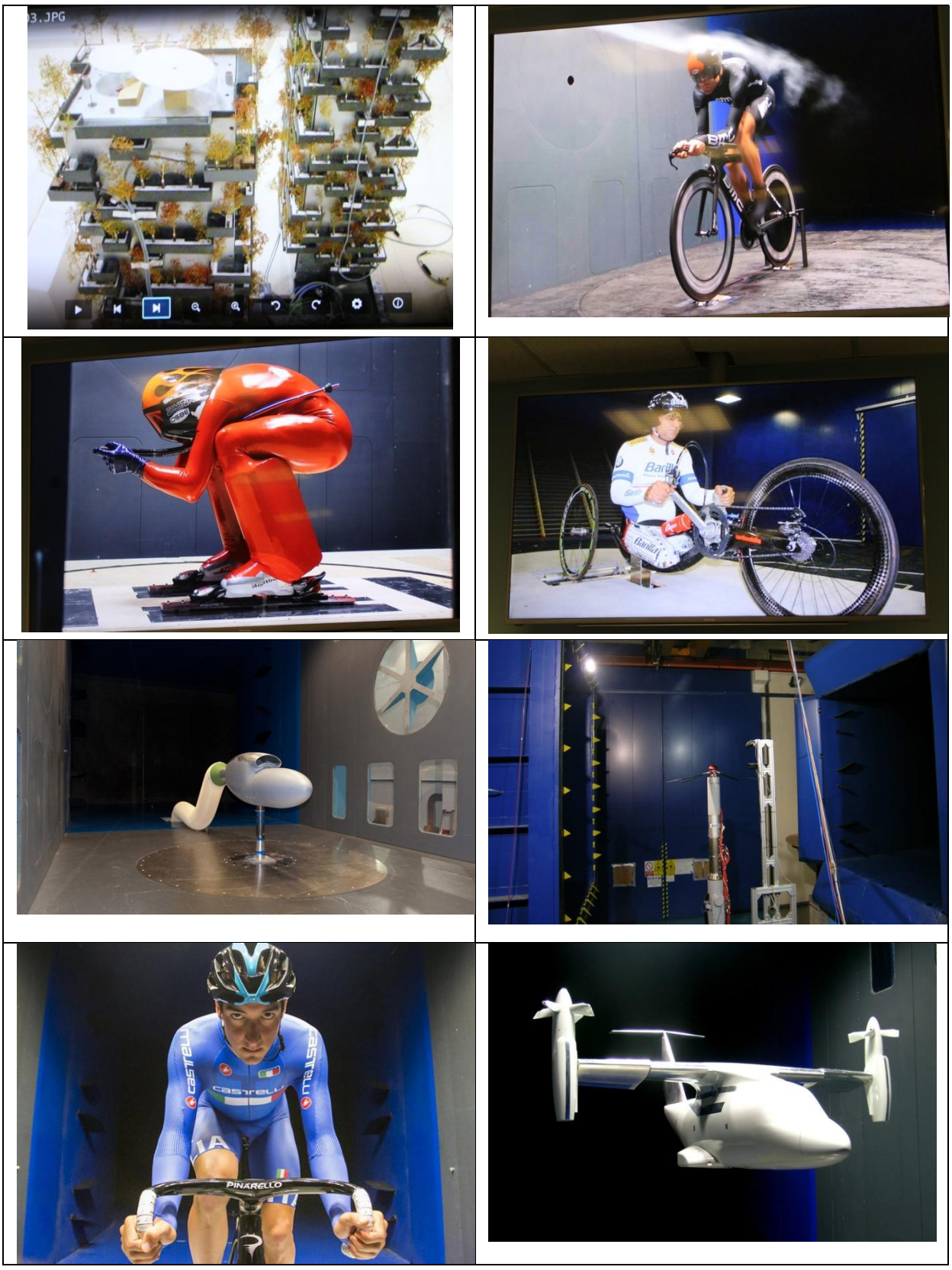


圖 37 GVPM 各項物件構造受風影響測試

圖 38 Danil 教授親自接待並導覽

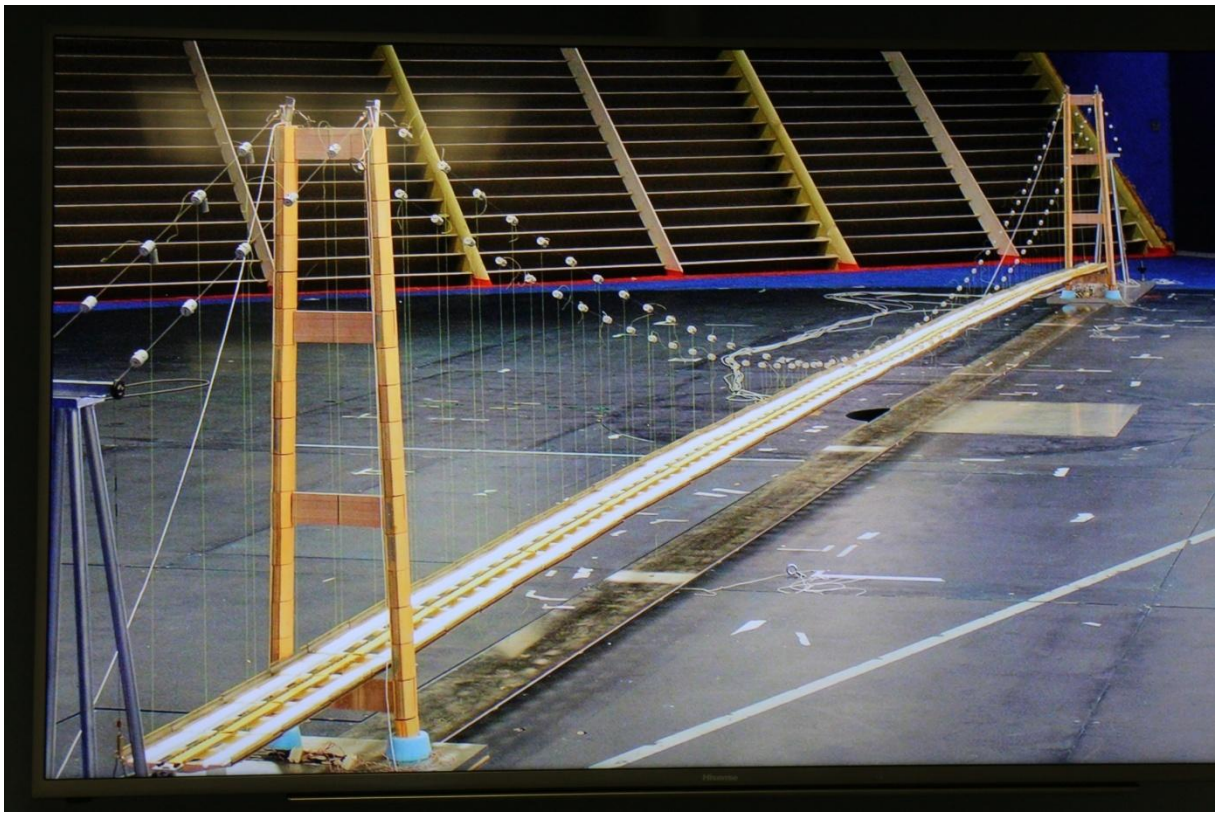


圖 39 懸索吊橋風洞試驗

由於近代橋梁構築技術之進步使得長跨度橋梁與日俱增,如懸索式橋梁與斜張橋等，其較為柔軟的特性提供了較佳之抗震性，但在抗風設計方面則顯得相對重要。長跨度橋梁除了有施工對環境衝擊較小之優點外，亦具壯觀之地標性，已成為目前國際間長跨度橋梁之首選橋型。相對於一般橋梁，懸索橋或斜張橋有著輕軟之結構特性，儘管其上部結構較具抗震性，然在抗風方面確實存在著敏感的氣動力穩定性問題，而這些問題則依橋梁斷面幾何形狀等因素呈現有同之氣動力行為。在強風下發生倒塌的實例以 1836 年英國的 Brighton Chain Pier Bridge 與 1940 年美國的 Tacoma Narrows Bridge 為最典型，其原因皆是因為輕軟橋體在強風中發生了顯著之振動，繼而因互制作用產生之氣彈力(aeroelastic)效應所致。

台灣位於颱風頻繁的地帶，平均每年受多次颱風的侵襲。因此，長跨度橋梁的受風效應是無法避免的。基於結構的安全性和使用上舒適性的考量，工程師必須將氣動力理論融入懸索橋橋梁設計中，亦須對風的效應有進一步的瞭解，才能避免由於風的效應造成橋梁不穩定現象的發生。

懸索式橋梁對風力所產生之反應頗為敏感，在風力設計上包括靜態與動態載重之考量，除須考慮以現地風速資料估算之平均風載重外，結構受風吹襲產生之氣動力效應(aerodynamic effect)亦為考量之重點。當結構受風力作用而產生振動時，會因其互制作用(interaction)導致橋體發生氣彈力(aeroelastic)效應。為確保這些懸索式橋梁的安全性，目前則須藉由風洞試驗與數值理論方法檢核之。

由於纜索支撐橋梁對風力極為敏感,此也是破壞主因之一。自 1940 年 Tacoma Narrows bridge 破壞之後,橋梁工程師才了解到氣彈力在纜索支撐橋梁設計上具有相當大之影響,因此開始就相關的反應作深入的探討與研究，以期了解橋梁氣動力的特性。然而，具鈍體外形之橋梁受風作用所引發的氣動力與流線型機翼並不相同，故為解決纜索支撐橋梁之氣動力穩定問題，首須了解作用於橋梁上之氣動力形式。

長跨度橋梁所受的風力具有強烈的隨機特性，其受風力作用產生的效應包括抖振效應(buffeting)、渦流(vortex shedding)引致之振動、扭轉不穩定現象(torsion instability)、風馳效應(galloping)與顫振 (flutter)效應等，茲分述如後。

1. 抖振反應

抖振效應是由於來流(approaching flow)中紊流之速度擾動對橋梁造成非恆定之風載重，使得結構體產生振動的現象。由於現階段並沒有準確且有效的紊流解析模式可供依

循，因此在實際應用上多假設外力符合準穩定定理(quasi-steady theory)然後再使用隨機振動理論(random vibration theory)來進行其效應之分析。

抖振反應不僅與來風之紊流特性有關，也受到橋梁斷面幾何形狀及橋梁基本振態影響。一般而言，橋梁的抖振效應通常不致造成橋體結構的破壞，但在設計風速下，若橋梁斷面有太大的位移量，會引起車輛和行人感到不適，亦可能在長期作用下使得橋體材料產生疲勞(fatigue)之虞。

2. 渦流引致之振動

渦流引致之振動發生的原因是由於氣流受到非流線形橋體的阻礙而產生分離(separation)，導致結構體的上下側產生規律且具週期性之渦流(vortex)。由於上下側交替形成的渦流具有相位(phase)之差異，造成了結構體上下表面壓力的不同，使得橋體產生不穩定的振動。若當渦流頻率與橋梁結構體某一振態之頻率相近時，則會造成共振(resonance)的現象，使得渦流頻率被鎖在橋體之基本頻率上，直到風速增加至脫離氣流與結構體共振作用之範圍方止。

因渦流引致振動所產生之垂直力，尤其在橋梁結構於低風速下垂直向的運動中扮演重要之角色。而渦流的頻率不但與風速有關，也和結構物形狀與大小有關；對於非圓柱形結構物，則與風攻角(attack angle)也有密切的關係。渦散頻率(NS)之表示式如下：

$$N_S = \frac{S_t U_0}{D} \tag{2-1}$$

其中，U_0 為來流平均風速；D 為結構體之迎風面寬度；S_t 為史特赫數(Strouhal number)，一般隨著橋梁斷面幾何形狀之不同而改變。

3. 扭轉不穩定現象

早期有關扭轉發散的研究始於在機翼之其扭轉運動上，而後期發現在類似於機翼的細長結構(如橋面版)情況中亦可能發生此現象。扭轉發散現象為一單自由度運動，其發生機制係當氣流方向與橋梁斷面呈某一風攻角時，則造成相應之扭轉彎矩及扭轉位移，繼使氣流相對之風攻角亦隨之增加，進而導致扭轉彎矩再形增加，如此反覆作用。而當到來風達到某一風速時，橋體所承受的扭轉彎矩超過其所能抵抗的能力時，則發生了因扭轉向不穩定的發散反應。扭轉發散類似於結構的挫屈問題，會造成橋梁全面性的破壞，因此在橋梁的設計風速內，必須避免此種破壞的發生。

4. 風馳效應

一般橋梁斷面並不受風馳效應影響。需要考慮風馳效應的橋梁元素包括鋼纜(cable)、吊索(hanger)或桁架桿件等。風馳效應是由於結構垂直向的振動速度與氣流速度的合成導致風攻角的改變並造成結構體運動的不對稱，進而影響垂直向的外力，此垂直向外力的變化繼引發氣動力阻尼，繼而改變結構垂直向的振動速度，使得攻角再度改變，如此反覆的交互作用造成結構的不穩定現象。

風馳效應經常發生在空中的運送線或斷面為非圓形的狹長結構物。由於風雨的作用會使橋梁上的纜繩表面形成水流(rivulet)或結冰，造成纜繩斷面的改變，而使得風馳效應產生。與渦流引致振動明顯的不同點是，因風馳效應產生的振幅非常大，有時可達垂直風向剖面尺寸的 10 倍以上，故應避免其發生。通常為防止此現象的發生可於纜繩表面做特殊處理以防水流的產生；或加裝阻尼系統，以降低纜繩的振動。

5. 顫振效應

顫振是一種氣彈力現象(aero-elastic phenomenon)，肇因於流體與結構體間的互制(interaction)行為。即當結構體的彈性位移影響了附近流體的行為變化，改變了結構體表面壓力與流體作用在結構體的力量，進而又使結構體的振幅產生變化。此壓力變化與結構體位移、速度相關聯者，分別可視為氣動力勁度與氣動力阻尼之效應，而顫振係發生於結構之總阻尼(材料組尼與氣動力阻尼之總合)為零之情況。早期研究中的氣彈力振動通常是指機翼(airfoil)的顫振，而在橋梁結構的顫振現象是一種由於橋體本身的微幅振動，經不斷從流場中吸取能量，當達到某一風速時振幅快速增大，使得結構破壞的自勵振動(self-excited oscillation)，而此風速即為該結構的顫振臨界風速(critical flutter speed)。若基於能量之觀點，橋體之所以會產生不穩定的運動是由於結構系統受到了一初始擾動，而則此結構的運動不是衰減(decay)就是發散(diverge)，必須根據此風所引發出來的運動能量小於或超出此結構系統的機械阻尼所能消散的能量。

一般橋梁結構的顫振效應可分為兩個種類，分述如後：

(1) 單自由度顫振(single-degree-of-freedom flutter)

流體經過斷面形狀為非流線形的結構時產生強大的分離流(separated flow)，進而發生扭轉向的不穩定現象。橋梁結構會發生此類型顫振主要是因橋梁結構體扭轉向阻尼發散所致，所以又稱之為阻尼驅動顫振(damping-driven flutter)。

(2) 古典顫振(classical flutter)

此乃流體經過流線形的結構時流場並未發生分離，而使結構體因垂直向與扭轉向耦合所引發的不穩定振動，亦即垂直與扭轉兩個方向的耦合顫振(coupled flutter)。造成此種現象的主因是因氣彈力現象改變了前述兩個自由度的頻率，使得原為不同頻率的自由度逐漸耦合在某一頻率上。理論上，扭轉向與垂直向之頻率比以及扭轉向與垂直向的相位差密切關係著耦合顫振是否能產生，故古典顫振又可稱之為勁度驅動顫振(stiffness-driven flutter)。

據前人研究可知，造成顫振效應的臨界風速和橋梁斷面的幾何形狀有很大的關係，且橋梁之顫振效應對橋梁會造成致命性之破壞，故橋梁最大設計風速必須小於顫振效應之臨界風速。

圖 40 大氣邊界層測試段寬 14 公尺

圖 41 GVPM 風洞縮小模型

圖 42 低紊流測試段

圖 43 可移動式低紊流測試艙

圖 44 低紊流測試艙內部

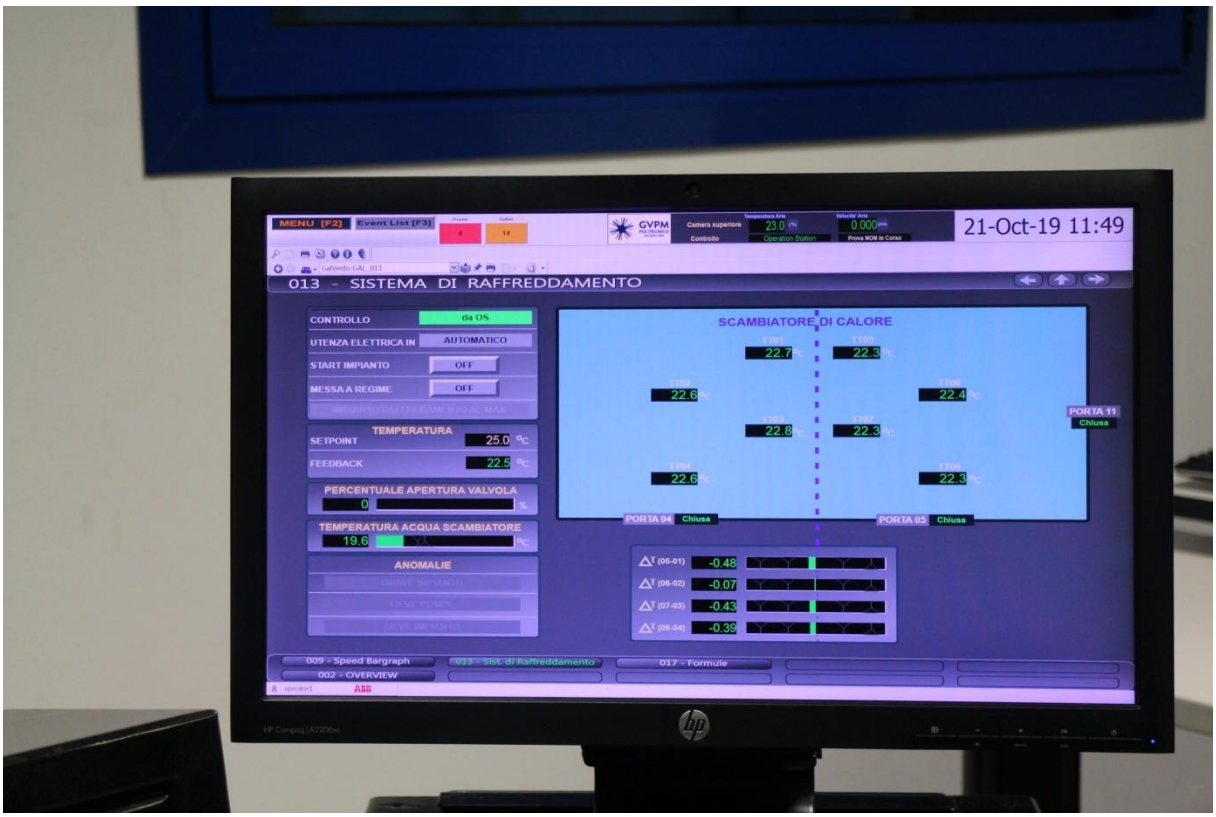


圖 45 GVPM 風洞儀控電腦程式

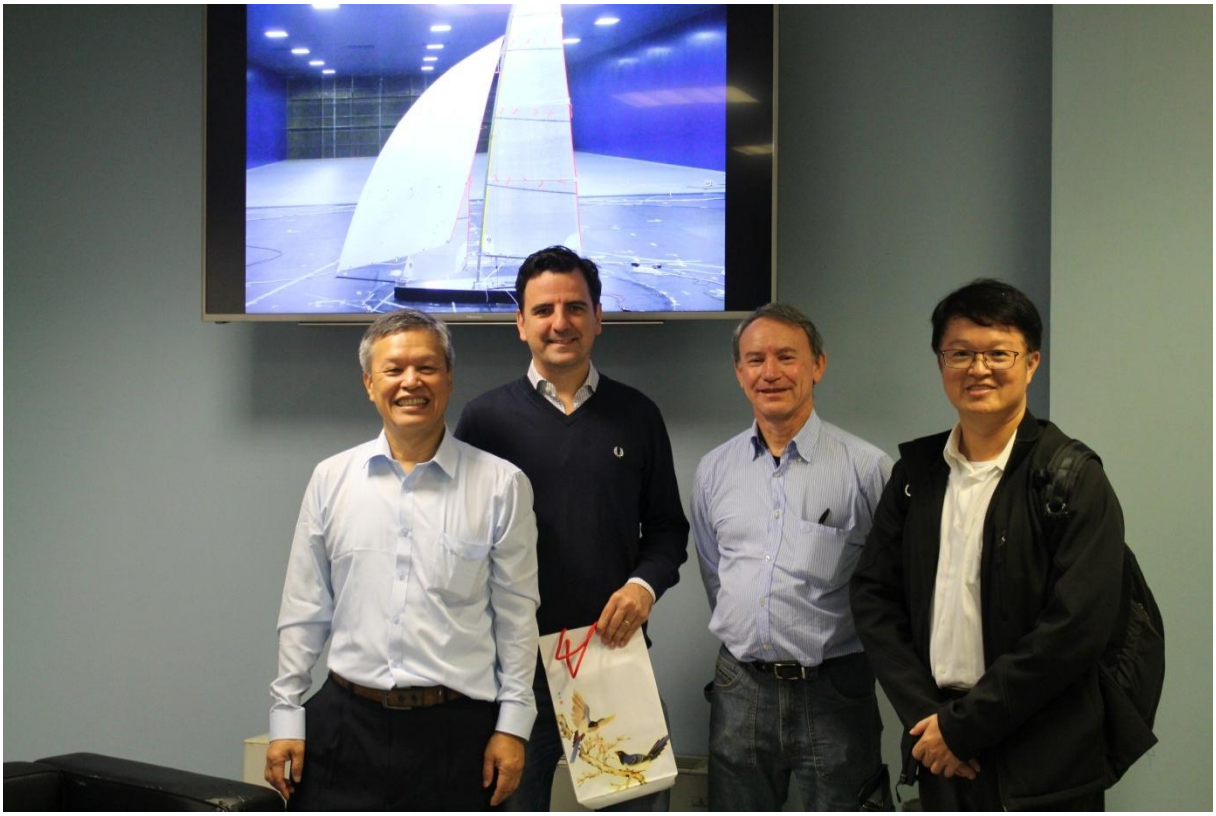


圖 46 與 Dainl 教授等人合影

五、拜訪佛羅倫斯大學營建與風工程氣動力學研究中心（CRIACIV）

(一) CRIACIV 實驗室介紹

佛羅倫斯大學營建與風工程氣動力學研究中心（CRIACIV）計有 30 名研究員人(教授、助理教授、研究工程師及研究助理)和數名碩士級工程師、博士生、大學生等。其營運董事會有 13 名成員，係由中心科學會員選舉產生，有主任、副主任和執行秘書各 1 名，各項事務的綜理則由佛羅倫斯大學土木與環境工程學系辦理。佛羅倫斯大學營建與風工程氣動力學研究中心負責營運一大尺度風工程大氣邊界層風洞實驗室，該實驗室位於佛羅輪斯大學 Prato 校區內，其為義大利在建築與環境氣動領域第 1 個實驗室。可針對某些結構類型（高層建築，大跨度橋樑，細長結構）以及研究某些環境現象（污染物在大氣中的擴散）受風影響時相關物理現象探討。

在比例模型上使用測試通常是評估一些所需數量的必要步驟。必須在邊界層風洞（BLWT）中進行測試，在該邊界層中以給定的規模再現大氣環流。BLWT 從入口到測試段的長度與航空的不同，這使得通過沿風洞插入的某些特定裝置可以正確地再現地球表面的粗糙度(然後是平均流量和湍流特性)。在位於普拉託的 CRIACIV 的 BLWT 中，使用約 160 kW 的功率可以達到高達 30 m / s 的風速。可以通過改變風扇葉片的槳距角和通過改變電動機的轉速來遠程控制風速。

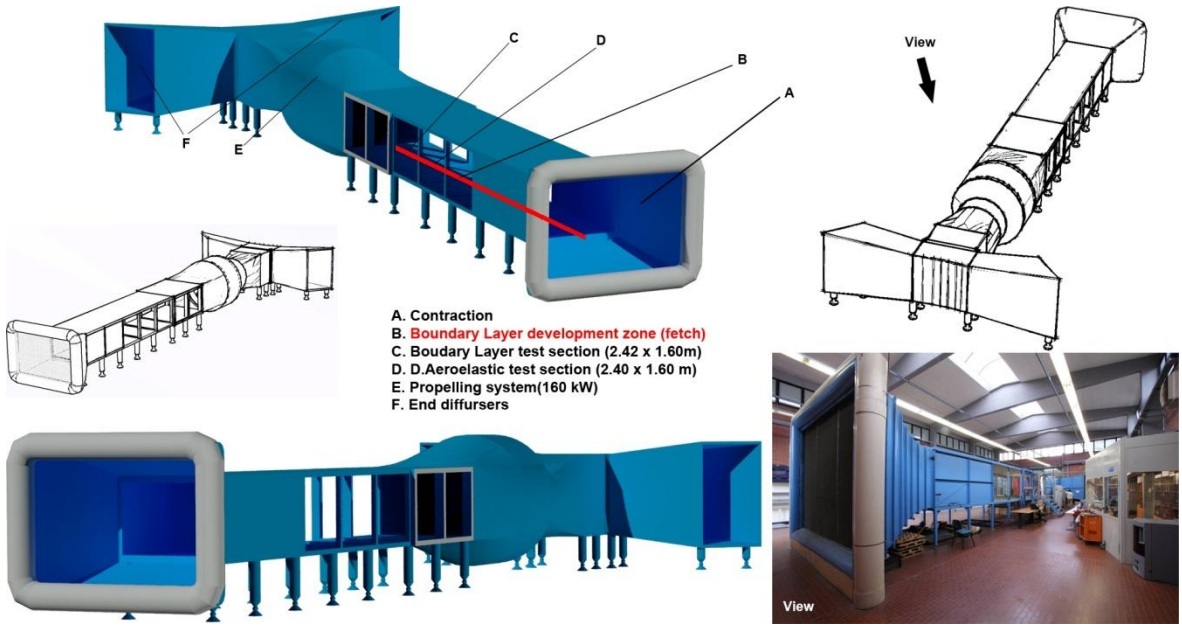


圖 47 CRIACIV 風洞斷面

圖 48 CRIACIV 風洞外觀

圖 49 Andrea Giachetti 博士導覽介試驗模型

圖 50 CRIACIV 風洞縮小模型

圖 51 Andrea Giachetti 博士導覽檢測案件

地表附近空氣的移動受到地面之起伏、建築物、林木作物分佈等的磨擦作用的影響，使得平均風速隨高度而變，形成一垂直分佈剖面，越接近地表風速越慢(參見圖 2-1)；換言之，此「風速剖面」直接受到地表粗糙狀況之影響。而影響所及的範圍就稱之為「大氣邊界層」。在邊界層頂部之風速通常稱之為梯度風速(gradient wind)。

一般風工程之應用所涉及問題大都發生在較強的風勢情況下，近地表上數百公尺高度的大氣邊界層範圍之內。在強風的情況下，大氣紊流作用遠超過熱對流作用。由於紊流之強制混合趨向於形成中性層差。所以本節對大氣邊界層之討論僅限於中性層差之大氣邊界層。

大氣邊界層之厚度，在中性層差的情況下，視風場之強度、地表之粗糙程度及所在之緯度而定，通常在數百公尺至數公里間。本研究風洞模擬實驗，很重要之一項工作即是要模擬邊界層高度內紊流流場的各項重要性質，其中包括有平均風速特性及紊流特性。

1.平均風速剖面

一般常用於規範邊界層風速剖面兩定律，一為指數律(power law)，另一則為對數律(logarithmic law)。

（1）指數律(power law)

邊界層流中水平方向均佈之地形上的平均風速剖面，以指數律表示：

$$\frac{U(Z)}{U_\delta}=\left(\frac{Z}{\delta}\right)^{\alpha} \qquad (1.1)$$

其中，U 為縱向之平均風速；Z 為地表上之高度；Uδ 為梯度風速；δ 為大氣邊界層厚度；α 為指數。在現行工程應用中之假設為：①一個α 為定值之指數律可是用至梯度高度δ 。②邊界層厚度δ 僅只為指數α 之函數。

（2）對數律(logarithmic law)

越接近地表的地方，其風速的擾動性越高，解析描述也就越加困難。在地表層(或稱之為常應力層)其剪應力值τ u 與地表面之剪應力值τ 0 極為接近，且其橫風向之風速分量 V 極小。對邊界層橫風向之平均風速方程積分至高度，再加以整理可得。

$$Z_l = b\frac{u_*}{f} \qquad (1.2)$$

其中，Zl 為對數律之有效高度；u＊為剪力風速＝(τ 0 /ρ)0.5；f 為科氏力參數；ρ 為空氣密度；b 為常數，其值約在 0.015 至 0.03 之間。微氣象學研究的一些結果顯示，在地表其平均風速剖面可用下式表示：

$$U(Z)=(1/k)\cdot \ u_* \ \cdot \ln(Z/Z_0) \qquad (1.3)$$

其中，k(=0.4~0.41)為馮卡門常數(Von Karman constant)；Z0 為地表粗糙長度(roughness length)。公式(1.3)即為所稱之對數律。實場量測結果指出，在強風之情況下，對數律之適用範圍可達數百公尺之高度。有關在不同地表情況下，上述討論之大氣邊界層各參數的建議值如圖 52 所示。各專家學者對不同風場有不同的定義，表 2 及 3 為我國建築物耐風設計規範與解說所定義的地況及其相關對應參數，進行任何耐風設計或風洞試驗地況模擬皆應滿況參數定義。

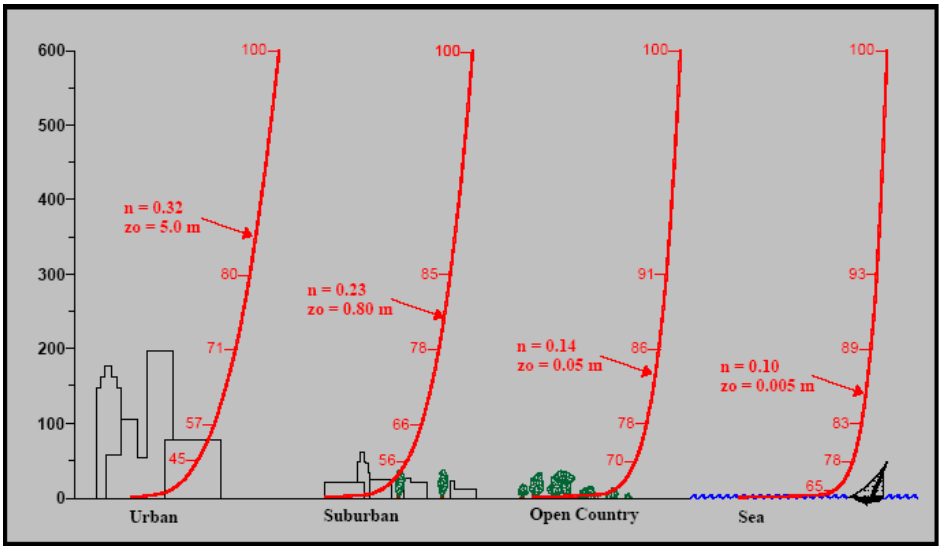


圖 52 不同地況下平均風速隨高度之變化示意圖

表 2 建築物耐風設計規範與解說建議之地況種類

地況 A	大城市市中心區，至少有 50%之建築物高度大於 20 公尺者。建築物迎風向之前方至少 800 公尺或建築物高度 10 倍的範圍（兩者取大值）係屬此種條件下，才可使用地況 A。
地況 B	大城市市郊、小市鎮或有許多像民舍高度（10~20 公尺），或較民舍為高之障礙物分布其間之地區者。 建築物迎風向之前方至少 500 公尺或建築物高度 10 倍的範圍（兩者取大值）係屬此種條件下，方可使用地況 B。
地況 C	平坦開闊之地面或草原或海岸或湖岸地區，其零星座落之障礙物高度小於 10 公尺者。

表 3 建築物耐風設計規範與解說建議之地況相關參數

地況	α	Z_g(m)	b	c	l	ε	Z_{min}(m)
A	0.32	500	0.45	0.45	55	0.50	18.0
B	0.25	400	0.62	0.30	98	0.33	9.0
C	0.15	300	0.94	0.20	152	0.20	4.5

2.紊流特性

紊流強度是紊流擾動流速大小的表達方式。將擾動風速之均方根值(root mean square)除以平均風速值，以百分比之方式表達出來，邊界層中某特定高度 Z 之紊流強度，其定義如下：

$$T.I.(\%) = \frac{\left(\overline{u_i^2}\right)^{0.5}}{U_i} \times 100\% \qquad (1.4)$$

其中，T.I.(%)為 i 方向之紊流強度；ui 為 i 方向上之擾動風速；Ui 為 i 方向之平均風速。而縱向擾動風速之均方根值與地表剪應力風速有下列關係：

$$\overline{u_i^2} = \beta \bullet u_*^2 \qquad (1.5)$$

其中，β 值通常假定與高度無關，一般工程應用上可取為 0.6。在非常粗糙的地況下，其值最低可達 0.4。

大氣邊界層中的紊流性質除了前述的紊流強度之外，紊流長度尺度(turbulence length scale)以及紊流頻譜密度函數(turbulence power spectrum density function)和交相關頻譜(cross-spectrum density function)都是風洞模擬時不可忽略的重要特性。

風洞試驗原理：

若要針對某一個風工程問題進行風洞試驗，實際流場與模擬流場間必須滿足流場相似性的要求，試驗結果才能正確地應用於實體的設計。相似性原理可分為幾何相似性(Geometric similarity)、運動相似性(Kinematic similarity)及動力相似性(Dynamic similarity)，以下分述之:

1.幾何相似性

建築物的幾何外型、相鄰地形、地物的配置皆可能會影響建築物周遭的風場和建築物所受的風力，因此實體建築物周遭的街道、其他建築物、植栽、圍籬、棚架，和建築物表面的凹凸狀況，譬如陽台、屋頂的突出物等，皆須按模型縮尺比例精準地製作，並正確地放置在其預定位置，以確保模擬風場的正確性。幾何相似性可分為:

(1)模型和真實建築物各方向之比例縮尺必須相同:

$$L_r = \frac{H_m}{H_p} = \frac{B_m}{H_p} = \frac{W_m}{W_p} \tag{1.6}$$

其中 H、B、W 分別代表建築物的高度、長度和寬度，下標 p 和 m 分別代表實體(Prototype)和模型(Model)，而 Lr 稱為模型的縮尺比。

模型的縮尺比例不宜太大或太小，太大的模型需要大風洞斷面，太小的模型則製作不易，建築物風洞試驗的縮尺比最好在 1/200~1/600。譬如建築物的實體高度 Hp=200m，寬度 Wp=50m，以 1/400 的比例縮尺製作模型，則模型的高度 Hm=0.5m，寬度 Wm=0.125m，為避免模型之阻塞比小於 5%，風洞試驗段的斷面積必須大於 1.25 m^2。

(2)建築物模型的高度必須與邊界層厚度成一定比例:

$$\left(\frac{H}{\delta}\right)_m = \left(\frac{H}{\delta}\right)_p \tag{1.7}$$

譬如大氣邊界層的厚度δ p=400m，建築物的高度 Hp=200m，若以 1/400 比例縮尺製作模型，則模型的高 Hm=0.5m，風洞中邊界層的厚度δ m=1.0m，而試驗段的高度必須大於 1.5m。

(3)建築物模型的高度必須與地表粗糙長度成一定的比例:

$$\left(\frac{H}{Z_o}\right)_m = \left(\frac{H}{Z_0}\right)_p \tag{1.8}$$

其中Z_o為地表粗糙長度。此無因次參數又稱為詹森數(Jensen number)，譬如市郊的地表粗糙長度 Zop=40 cm，以 1/400 的比例縮尺製作模型，則風洞中粗糙長度 Zop=1.0mm。

(4)建築物模型的高度必須與紊流的積分長度尺度成一定的比例:

$$\left(\frac{H}{L_x}\right)_m = \left(\frac{H}{L_x}\right)_p \tag{1.9}$$

其中 Lx 為紊流的積分長度尺度(Integral length scale)，可由紊流流速自相關函數積分

求得，邊界層流中的積分尺度約為 Lx≒0.3δ 。

(5)圓弧形建築物:

氣流通過圓弧形物體表面時會產生渦流分離現象，渦流的分離點與雷諾數及物體表面的粗糙度有密切的關係。平滑表面的流況較接近層流邊界層，分離點位於物體前方，尾流區會較大粗糙表面容易發展成為紊流邊界層，當雷諾數大於一個臨界值時，分離現象於物體後方發生尾流區較小。表面越粗糙的物體，臨界雷諾數越小。若建築物的整體或一部分為圓弧形設計，建築物模型的表面粗糙度必須遵守:

$$\left(\frac{\varepsilon}{D}\right)_m = \left(\frac{\varepsilon}{D}\right)_p \tag{1.10}$$

式中ε 為物體表面的粗糙長度，D 為圓弧直徑。

(6)模型的範圍:

因為建築物周遭的場與建築物的幾何外型、相鄰地形、地物的配置皆有密切的關係，尤其是行人風場會受到實際高度高於 0.5m 之植物的影響，故所有預定種植的灌木與喬木皆需以模型置於正確之位置。一般而言，除非特別高的超高層建築物，建築物影響半徑範圍約為:建築物斷面積方根的 8 倍或建築物高度的 3~5 倍。舉例而言，一棟高 100 m，寬度 50 m 的建築物，迎風面積方根的 8 倍約 560m，若以建築物高度計算影響半徑則為 300~500 m。若模型縮尺比為 1/400，則模型半徑為 0.8~1.4m，亦即風洞寬度至少需要 1.6~2.8m 以上。

2.運動相似性

運動相似性要求風洞試驗中任意兩點的流速比和實際流場中對應位置流速比必須相同，亦即流場的流速要成一定的比例。

(1)速度比例:

模擬流場與實際流場流速要成一定的比例。換言之，風洞中任意兩點的流速比與實際流場中對應位置的流速比相同。一般以邊界層外之自由流風速 Uδ 為參考風速:

$$\left(\frac{U(z)}{U_\delta}\right)_m = \left(\frac{U(z)}{U_\delta}\right)_p \tag{1.11}$$

風洞試驗所採用之風速 Uδ 大多介於 10~20m/s 之間。

(2)黏性次層:

物體表面會有一層極薄的黏性次層，其厚度約為:

$$Z = 11\frac{\nu}{u^*} \tag{1.12}$$

式中 u^* 為剪力速度，ν 為空氣的運動黏滯係數。風洞試驗中黏性次層的厚度約為 1.0mm，若量測位置之高度小於黏性次層的厚度，則所量測得之風速因受到流體黏滯性的影響，便無法滿足紊流流場的相似性。譬如行人風場的實際高度為 1.5~2.0m，若建築物縮尺比為 1/400，則風洞試驗需量測離地表 4.0~5.0mm 高度處之風速，若此量測高度小於黏性次層的厚度，則量測得之風速無法正確地反應出實場的紊流流速。同樣地，若採用較小的模型(較小的縮尺比例)，則黏性次層的影響會更嚴重，亦即縮尺效應(Scale effect)會造成試驗結果失真(Wang et al., 1996)。

3.動力相似性

動力相似性要求模擬流場與實際流場中流體所受之力要成一定的比例。依據流體力學的原理，若風洞試驗和實際流場的無因次參數相同，則流場的動力相似便可滿足。以下分別對一些重要的無因次參數做一介紹:

(1)雷諾數(Reynolds number):

$$R_e = \frac{UL}{\nu} = \frac{\rho UL}{\mu} \tag{1.13}$$

式中 U 為流場的特徵速度，ν 為流場的運動黏滯係數，μ 為動力黏滯係數，ρ 為流體的密度，L 為流場的特徵長度。雷諾數的命名是為了紀念英國學者雷諾(Reynolds,O., 1842-1912)。邊界層流中，特徵長度為下游距離或邊界層厚度;建築物尾流中，特徵長度為建築物之高度或寬度。不論何種流場，雷諾數皆代表流體的慣性力和黏滯力效應之比，當雷諾數小時，黏滯力大於慣性力，流場中的擾動會因為黏滯力而衰減，流體的流動趨於穩定，流況屬於層流(Laminar flow);反之，雷諾數大於一臨界值時，微小擾動則會因為慣性力而增強，形成流況紊亂的紊流流場(Turbulent flow)，雷諾數的臨界值視流場而定。

圖 53 CRIACIV 風洞大氣邊界層模擬擾流板

圖 54 CRIACIV 風洞大氣邊界層模擬粗糙元

圖 55 CRIACIV 風洞外視圖

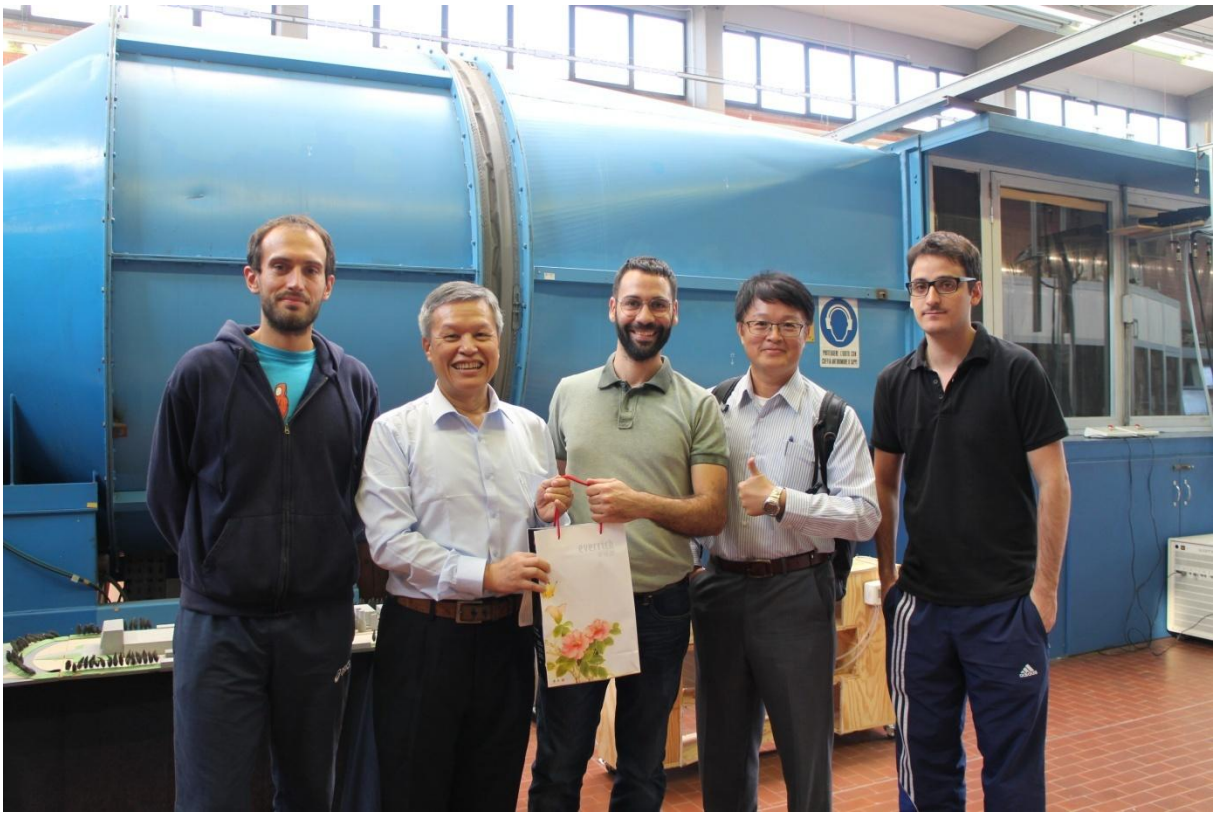


圖 56 致贈 CRIACIV 風洞實驗室人員紀念品並合影

參、心得與建議

本次赴捷克及義大利執行「歐盟都市災防應變與建築風環境先進試驗技術參訪觀摩研習計畫」，除拜訪捷克UCEEB實驗室及捷克理工大學土木工程學院室內環境與建築工程設備系，主要考察拜訪捷克科學研究院理論與應用力學所(ITAM)之環境風洞實驗室；義大利米蘭理工大學的GVPM 風洞實驗室及佛羅倫斯大學營建與風工程氣動力學研究中心CRIACIV之大氣邊界層風洞實驗室等3個風洞實驗室。

ITAM風洞實驗室特色的是環境測試段(climatic section)，在風洞內可噴水調節降雨強度和水滴大小，以模擬與毛毛雨或大雨相對應的效果，並控制室內溫度。此為世界各國風洞實驗室少有之功能，人員配置上僅研究人員1-2名，但有人力需求時可由其他地方調派人力支援；經費來源分配約為檢測案件10%、研究計畫經費20% 、政府預算70%。GVPM風洞斷面寬14公尺，可執行大尺度的橋梁全橋模型風洞試驗，其他大型場館或構造物之縮尺試驗。另外，有兩個低紊亂測試段(移動式可交替使用)，可快速且有效率執行各項商業檢測案件，因此其經費來源以商業檢測案件為主，在人力上則有5名教授和5名技術人員，為較具規模之風洞實驗室。CRIACIV風洞實驗室為義大利歷史最久之風洞，斷面尺度較小，主要用於學術研究，具有完整的研究團隊，經費學校為主，亦執行商檢業測案件，但案量不多。而本所風洞實驗室為國內最大斷面風洞實驗室，主要執行研究試驗作為我國耐風規範之修訂依據，輔以執行商業檢測案件作為儀器設備維護，經費來源20%科技計畫、80%檢測案件。以上所述之各風洞實驗室之分析比較如下表3所示：

表 3 捷克、義大利與本所風洞實驗室比較表

實驗室	風洞尺寸	人力配置	經費來源	風洞特色
捷克科學院理論與應力所 ITAM	測試段的斷面為寬 2.5×3.9 m 的矩形截面，長度為 9.0 m。 在此部分中，風速為 0.8 到 18 m / s，具有噴水及紅外線輻射系統。	研究人員 1-2 名	10%檢測 20%研究計畫 70%政府預算	ITAM 風洞實驗室有兩個測試段，氣動力測試為一般風洞測試段。較具特色的是環境測試段(climatic section)，在風洞內可噴水調節降雨強度和水滴大小，以模擬與毛毛雨或大雨相對應的效果。
義大利米蘭理工大學風洞實驗室 GVPM	低紊流測試段斷面寬 4m ×高 3.84m × 6m， 最高風速可達 55m/s。大氣邊界層測試段寬 13.84m ×高 3.84m ×長 35m， 最高風速 16m/s。	教授 5 名 技術人員 5 名	商業檢測案為主要經費來源。	GVPM 風洞斷面大，可執行大尺度的橋梁全橋模型風洞試驗，其他大型場館或構造物之縮尺試驗。另外，有兩個低紊亂測試段(移動式可交替使用)，可快速且有效率執行各項商業檢測案件。
義大利佛羅倫斯大學營建與風工程氣動力學研究中心 CRIACIV	測試段寬 2.4 m×高 1.6m，最高風速 30m/s	教授 2 名 研究員 1 名 研究助理 3 名 技術人員 1 名 博士候選人 2 名	大學經費為主，亦執行商檢業測案件，但案量不多。	CRIACIV 風洞實驗室在義大利歷史最久，所以斷面較小。主要用於學術研究。
內政部建築研究所風洞實驗室 ABRI	建築測試段：寬 4.0m×高 2.6m 長 36.5m，最高風速可達 27 m/s；橋梁測試段：寬 6.0m×高 2.6m 長 21m，最高風速可達 20m/s。	研究人員 2 名 技術人員 1 名	科技計畫經費 20%，實驗室收支併列 80%。	主要執行研究試驗作為我國耐風規範之修訂依據，輔以執行商業檢測案件作為儀器設備維護之經費來源。

本次執行「歐盟都市災防應變與建築風環境先進試驗技術參訪觀摩研習計畫」，參訪捷克義大利風工程相關實驗室，瞭解各實驗室因國家建築特色、定位取向及人力配置考量，而發展各種不同規模與定位之實驗室，執行此次考察計畫後，可借鏡他山之石，作為本所實驗室試驗研究發展與營運參考，相關建議如下：

一、 水可載舟 亦可覆舟，風可引致災害亦可形成能源。本所風工程科技計畫一直以風災的預防，探討構造物受風載重與風壓係數，以確保使用安全。對於綠能的應用則較少著墨，從參訪過程瞭解到，國外風洞亦積極探討如何有效利用風能等議題。本所風洞實驗室或相關研究計畫應配合當前政府發展綠能政策，發展綠能相關研究。

二、 本所風洞實驗儀器設備精良，試驗技術水準不亞於國外實驗室。經此次參訪後，與受訪實驗室適當維持連結並發展後續合作可能性，或與國內大學合作申請科技部計畫辦理技術人員互訪，甚至共同辦理實驗室間試驗能力比對，拓展國際視野，增加國際交流。

三、 本次參訪實驗室各具有不同之發展定位，形成自身之明確特色。本所風洞實驗室以研究試驗作為法規修訂依據，並輔以執行商業檢測案件。現有人員雖於風工程領域各有不同面向專長，但因研究人力不足，實驗室缺乏全面性研究人才。為補此不足，建議應與國內大學或相關研究機構，在設備使用、人力支援與研究議題上積極合作。

四、 風工程是門冷知識，但可應用性相當廣泛，建議本所應辦理風工程研討會、座談會、教育訓練與推廣，強化國內政府部門、建築師、技師、產業界與民眾對風工程的認識，以深化風工程之推廣與普及。

Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences

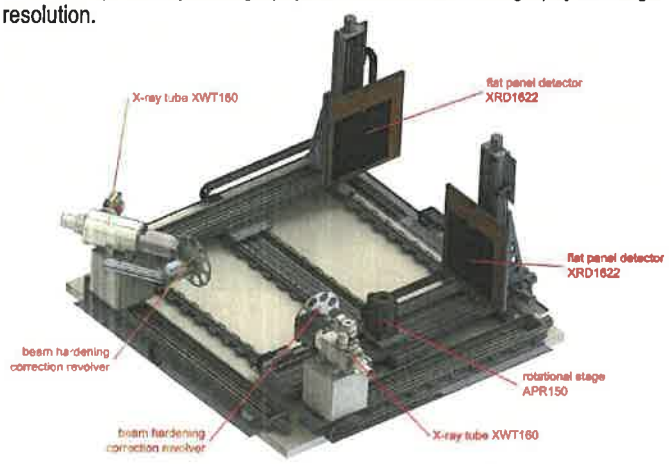
Akademie věd České republiky
Czech Academy of Sciences

Centre Telč

The Centre Telč (CET) is part of ITAM CAS. It was established as an **European research infrastructure for the interdisciplinary research of cultural heritage** funded by the European Union and Czech Republic as part of the Operational Programme "Research and Development for Innovations" for 2007-2013.
The Centre Telč is equipped with a **unique infrastructure** for expert research as well as development and verification of **advanced methods for diagnostics, enhancement of durability of materials and structures** and their parts, **preventive protection** and **preservation** as well as long-term **sustainable use** of both **cultural heritage** and **existing building** stock.

Research Infrastructure

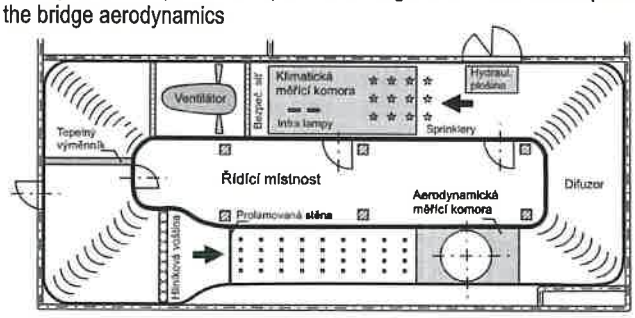
- Climatic and wind tunnel "Vincenc Strouhal", which is designed as an enclosed circuit with wind speed regulation and possibility to control a number of weather parameters - cyclic changes in temperature in a range of ±5°C, various intensity of rainfall (both rain and snow) and radiant heat radiation. For this purpose, the tunnel is equipped with two measuring chambers. The aerodynamic section is used for the study of static and dynamic effects of wind using down-scaled models of structures, buildings or landscape or using real-sized structural elements. The climatic section is used for experiments simulating combinations of effects of wind with weather impacts.
- Laboratory of X-ray Tomography, micro- and nano-tomography with high resolution.



- Set of physical, chemical and biological laboratories for complex material analysis and study of their degradation, durability and options for preventive protection or preservation.
- Laboratory for diagnostics of materials and structures, equipped with a mobile unit with a number of world-class diagnostic instrumentation for field measurements.

Examples of services offered

- Measurement and simulation of wind pressure on buildings or sets of buildings with complex shapes (tall buildings, heritage buildings, sculptures, facade envelopes and roof decks etc.)
- Measurement of aerodynamic instability of bridges, poles and towers
- Simulation of stratified air flow
- Study of well-being in public premises, sports facilities etc.
- Simulation of water penetration under wind-driven rain and measurement of efficiency of hydrophobic surface protection
- Study of frost deposit development on bridge cables and their impact on the bridge aerodynamics



- Micro-tomography of complex structures under load (bones, composites)
- Complex measurement of porosity of inorganic composites and their fracture properties
- Complex physical/chemical and biological analyses of historical materials, assessment of their condition and proposals for preservation or preventive protection
- Measurement of nanoindentation characteristics
- Measurement of thermal expansion
- Tests of material degradation under various climatic loads in the climatic wind tunnel Vincenc Strouhal and in climatic chambers (gas mixes, solar radiation, salt mist)
- Field diagnostics of condition of wooden structures including measurement of strength using a patented miniature press

- Diagnostics of condition of buildings affected by natural disasters and proposals for their preventive protection
- Assessment of buildings damaged by natural disasters and proposals for recovery measures
- Estimates of impacts of mass tourism or development projects on cultural heritage.

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Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences

ITAM ARCCHIP

Akademie věd České republiky
Czech Academy of Sciences

About us

ITAM has a reputation of a **top-level research institute** with an application potential for **construction and engineering**. Its origins date back to 1921. The Central Laboratory for Experimental Mechanics (CLEM) and associated laboratories dispose of broad experience with resolution of complex tasks for industrial applications, among others. The research is mainly focused on **structural and dynamics analyses** as well as **analyses of structural properties, nonlinear and stochastic environment mechanics, material mechanics** and **fault analysis, biomechanics** and **reliability and durability of structural elements.**

Competence

CLEM disposes of unique instrumentation infrastructure, which - thanks to the modular system of hydraulic actuators - allows implementation of multi-axial structural tests; moreover, the lab owns several loading frames with a capacity of 500 kN for various material tests. CLEM is equipped with two vibration tables for simulation of seismic loads and support walls for dynamic and fatigue tests. Furthermore, CLEM's employees work on the development of instruments applicable both in laboratory and on in-situ structures (examples include a portable driver unit for fast load testing of bridge structures).
With its application laboratories, ITAM offers a wide research potential. Highly qualified scientific staff is a matter of course.

Examples of services offered

Central Laboratory for Experimental Mechanics
- Loading tests of structures and their parts, determination of load bearing capacity of structural elements, determination of dynamic characteristics and vibration amplitudes of structures, measurement of both static and dynamic strain, design of dissipative devices
- Dynamic safety assessment
- Measurement of micro-vibration and technical seismicity in endangered areas and determination of human exposure to undesirable mechanical vibration
- Organization and implementation of dynamic loading tests for bridges, footbridges and structures
-Laboratory/field vibration measurement
- Specialized calculations and numerical solutions

Laboratory of Optical Methods
- Development of unique measuring and loading instrumentation for digitalisation of surfaces, e.g. assessment of their 3D shape, colouring and roughness

The Fracture Mechanics and Fatigue Laboratory
- Safety, integrity and operational reliability of pipe systems and other thin-walled systems (determination of fracture toughness and other mechanical parameters of materials, assessment of fatigue behaviour, determination of critical defect size, determination of impact toughness, assessment of safety and residual life of defective pipeline system, assessment of impacts of defects in welds, corrosion fatigue, general corrosion, pitting corrosion etc.)
- Material fatigue (due to mechanical loading, chemical action and combinations of impacts; study and determination of limit micro-plastic strain for steels etc.)
- Fracture mechanics (e.g. determination of fracture toughness and its practical application)
- Material research (creep properties, hydrogen embrittlement, corrosion fatigue etc.)

- Safety research
- Tests of structural elements, life prediction and determination of strength

Laboratory for Analysis of Particulate Media
- Extensive material analyses, e.g. moisture and water soluble salts content in masonry, composition and description of material microstructure (chemical and phase composition, granularity, porosity), sorption properties of construction materials (water absorption and water desiccation rate), diagnostics and monitoring of wooden structures, study of effects of preservative materials and technologies

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newsletter

Czech Academy of Sciences

ITAM ARCCHIP
INSTITUTE OF THEORETICAL AND APPLIED MECHANICS

Centre of Excellence Telč

1 / 2018

SCOLA TELCZ 2018

The interdisciplinary workshop Scola Telcz 2018 was held in Telč from the 5th to the 9th of February in 2018. Students from three universities in the Czech Republic and from Austria attended the workshop. The main topic was conducting case studies of the renewal and further use of a former synagogue.

The "winter school" program consisted of lectures by experts, fieldwork demonstrations and, in particular, independent creative work of student teams. The program also included a detailed introduction to the historic center of Telč, the town where the investigated object is located. Participants had a unique opportunity to access otherwise inaccessible places and to closely cooperate with specialists from various fields such as conservationists, architects and representatives of the disciplines of science and historical art. The student teams were diverse, enabling participants to try out the interdisciplinary cooperation typical of work in the field of heritage care. However, the assignment was the same for all teams – to prepare an initial study for the reconstruction of the Telč synagogue building. The week-long event culminated on Friday with a public presentation of the results of the individual teams directly on the premises of the former synagogue.

Scola Telcz 2018 was organized by the CTU in Prague, Masaryk University in Brno, Danube University in Krems, the Center of Excellence Telč of the ITAM CAS and the Telč department of the National Heritage Institute. Scola Telcz is one of the results of their long-term cooperation in the field of heritage science.

J. Novotný

EDITORIAL

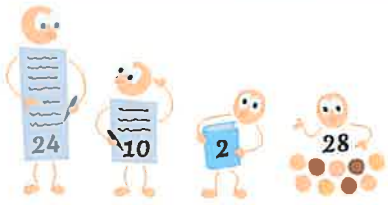
Dear readers, You are now holding another Newsletter of the Institute of Theoretical and Applied Mechanics of the CAS and the Centre of Excellence Telč. ITAM's employees can again boast of many scientific findings, and it is especially encouraging when some are even recognised by the management of the Academy. Their visit on February 8th was the first visit to the Institute from the first scientific area. The members of the CAS' management heard the Activity Report and the future conception of ITAM and CET. A lively debate about basic and applied research ensued. Judging both from their immediate and subsequent reactions the visit was a success.

Some of our most interesting research projects are presented here. One of them is the research of a team specializing in analysis of wooden structures from the point of view of both traditional technologies and new scientific findings. Another topic, successfully researched over a long period, is the study of the deformation of bone scaffoldings using 3D dynamic radiography. Also, there is an article about a study on wind turbines, which is an interesting subject from an aerodynamics point of view. Researchers at the wind tunnel at CET have managed to develop and test a relatively reliable model of a wind turbine scaled 1:385, from which, among other things, the acting forces on a prototype and its effectivity can be predicted.

The results of our work are presented mainly in journals, at conferences and in workshops. One of the last meetings took place in March in Montagnana, Italy, as part of the project RUINS. Another source of inspiration for scientific work are the so-called "mobilities" of researchers, about which we've also written. In short, there is no shortage of interest in the cooperation, internships and scientific work at ITAM and CET. I wish you an amusing read.

Stanislav Pospíšil, director of ITAM

CET 2017 IN NUMBERS



24 articles in peer-reviewed impact journals
10 articles in other peer-reviewed journals
2 chapters in books
28 papers at international conferences
1 patent & 1 utility model
6 functional samples
25 research projects

Use of CET infrastructure:

88 researchers from the Czech Republic and abroad
54 students in master's or doctoral programs from the Czech Republic and abroad

WHAT IS NEW IN WOOD RESEARCH?

Use of all-wooden joint during reconstruction of rafters in Bratronice castle

Wood and timber structure research has been a long-term topic at ITAM CAS. Thanks to efforts to reconstruct historical buildings using traditional technologies and new scientific knowledge, carpentry and traditional woodworking have become popular again in recent years. The research on all-wooden joint behaviour, supported by NAKI run by the Czech Ministry of Culture (CMC) from 2012 to 2015, was concluded with the publication of a certified handbook about the static design of the joints. The relatively successful implementation of the handbook into practice has stimulated further research and led to the handbook being revised and supplemented so that it can be used in more cases. Currently, experimental testing is being done on a large series of specimens of 1:1-scale four-doweled joints (see Fig. 1), which should serve as verification of the part of the design diagram corresponding to the combination of bending and compression loading. It will influence joint design for repairing rafters (a combination of higher compression and lower bending). The greatest ambition of the current experimental research is to design a joint that will be more efficient under high tension loads (e.g. tie beams). Optimally, it should combine the functions of a peg (docking and tightening the joint faces) and a dowel (clasping the laps, easily defining their manufacture). The joint will be tested in the following months at the real dimensions (cross-section 200×240 mm, length 6 m) in tension and bending until rupture (the load-bearing capacity is estimated to be about 80 kN).

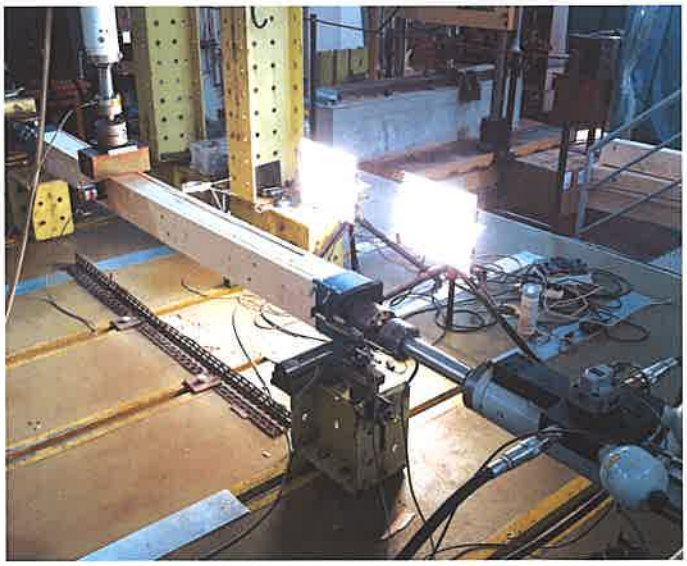


Fig. 1 Testing of all-wooden joints for use while repairing rafters in historically valuable structures

Mathematical modelling is part of the research. The question of practice – How will the application of the joint during a repair influence the distribution of forces in the structure? – led to an interesting numerical simulation. The change in the structure's stiffness was studied on a set of rafters of a simple collar-beam construction. The middle rafter was repaired "virtually". The joint in the element was loaded with a combination of normal compression force N and bending moment M. The construction was loaded in three steps while the lathing and sheathing was added gradually. The model and bending moment distribution after final loading are shown in fig. 2. The length of the rafters was 3.6 m and their cross-section was 140×180 mm. The results show that repairs always increase the strain on adjacent elements and other structural elements are also influenced. A harmonious effect is present in the surrounding elements when the load is alternately increased and decreased.

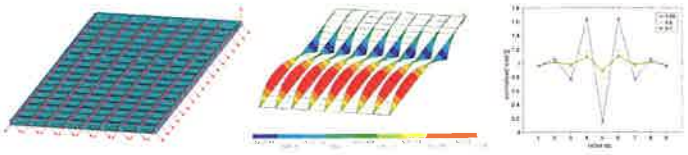


Fig. 2 a) Model of rafter set created by ANSYS software, b) distribution of bending moment, c) influence of all-wooden joint application (position no. 5) on strain distribution in the other structural elements after being fully loaded (values of model bending stiffness kmodel – missing element kmodel = 0,05, joint positioned in the third of element kmodel = 0,5, joint close to element end kmodel = 0,7).

There are two other projects in the field of wood nowadays. The project Historical timber structures: Typology, diagnostics and traditional woodworking, supported by CMC, is a critical analysis of the processes used in woodworking and the following specific proposals for optimizing the restoration, conservation, repairs and maintenance of historical wooden constructions. The partial aims are the systematization of roof structures based on design-typological classification, the application of advanced methods in the diagnostics and monitoring of physic-mechanical behaviour of timber structures and the design of construction and remediation measures suitable for the restoration of monuments on the basis of the traditional craft of woodworking (including correct log selection in the woods, the felling period, the elimination of growth stress during machining, wood response to different machining methods).
The last project is Oak fastener in timber structures: Materials for normative anchorage, which is financially supported by TAČR due to the possibility of wider application in practice. Mendel University in Brno and the University Centre for Energy Efficient Buildings CTU are participating in the project. The research has been divided into three parts (load-bearing capacity of the fastener related to its material and geometry, behaviour and load-bearing capacity of the surrounding mass, long-term behaviour of the loaded fastener in various humidity conditions).

Related new publication
Kunecký Jiří, Hasníková Hana, Kloiber Michal, Milch Jaromír, Sebera Václav a Tippner Jan, 2018. Structural assessment of a lapped scarf joint applied to historical timber constructions in central Europe. International Journal of Architectural Heritage (Conservation, Analysis, and Restoration). 18, 1-17. ISSN: 15583058.

The certified handbook Lapped Scarf Joints for Repairs of Historical Structures is available along with other information at www.itam.cas.cz/spoje.

Questions can be sent to spoje@itam.cas.cz.

H. Hasníková, M. Kloiber, J. Kunecký

MEASUREMENTS OF AERODYNAMIC FORCES ON WIND TURBINES

Under the ongoing project WESLO (Wind and Sea Loads on Energy Structures), the team from the Department of Dynamics and Stochastic Mechanics started experiments on wind power turbines with horizontal rotation axes. Classical, mainly three-bladed, wind power turbines are being analysed. They can achieve, using the most recent technologies and knowledge, a maximum power of 9 MW. The diameters of the propellers reach dimensions of over 170 m and the heights of the shafts up to 220 m. The flow of wind on a structure of these dimensions constitutes a heavy load. Moreover, the rotation of the propeller creates additional gyroscopic and centrifugal forces that have to be taken into account when making the design. A detailed knowledge of all the forces at work make it possible to propose larger, and therefore more efficient, wind turbines. Our team is currently working on analysing the effects of wind load on wind turbines using scaled models in the Aerodynamic climatic tunnel at the Centre of Excellence Telč. Using a scaled model of the wind turbine, we are able to predict the expected load intensity on real-life structures for the wind turbine's different modes of operation and the different flow conditions influenced by, i.e., the location in the terrain, intensity of the wind turbulence, and incident angle of the wind flow with respect to the propeller plane. The model was made on a 3D printer. A small three-phase outrunner brushless motor was used in place of a real generator, thanks to which very precise measurements can be made and the rate-of-turn can be changed smoothly. As we know how much energy the experimental model of the wind turbine produces, we can deduce the generator's braking forces and therefore the torque of the propeller at different speeds. The forces in the base of the tower are measured with a dynamometer, which makes it possible to measure 3 force components and 3 bending moments.
Future experiments will be focused on aerodynamic and aeroelastic force application in the context of the location of the wind turbine in more complex terrain.

M. Macháček

NEW INSTRUMENTS AT CET

New isocalorimeter

The materials research team at CET has a new instrument called isothermal conduction calorimeter. It can monitor the thermal activity and heat flow of chemical, physical and biological processes. The information provided cannot be obtained using other techniques. It is particularly useful when investigating hydration processes in cements, concrete and mortars and when determining the heat of hydration or studying the effects of components added to retard reactions or improve material performance. It can also be applied to monitor the stability of drugs, like antibiotics, or the self-discharge of batteries, to determine their shelf-life.
The sample is placed in an ampoule that is in contact with a heat flow sensor that is also in contact with a heat sink. When heat is produced or consumed by any process, a temperature gradient is developed across the sensor. This generates a voltage which is measured. Up to 8 samples can be accommodated, and they can be measured simultaneously and independently of each other.

A. Viani

DEFORMATION ANALYSIS OF ARTIFICIAL BONE SCAFFOLD USING ON-THE-FLY TOMOGRAPHY

In bone tissue engineering, the accurate description of deformation behaviour in both original bone and artificial replacements is one of the most important prerequisites for the assessment of biocompatibility and bone-integration characteristics of a proposed structure intended for use as a bone scaffold. A newly synthesized hydrogel-based bone scaffold was subjected to compressive loading to obtain its deformation characteristics. Its very soft nature and high porosity together with the low X-ray attenuation of the material required the development of an experimental method employing an in-house designed micro-loading device and a CT device operating in on-the-fly mode. The sample was compressed at a loading rate of 0.4 microns per second.
To evaluate the displacements and strains on the deforming microstructure, the digital volume correlation method was employed on the reconstructed tomographical images. In total, 34 CT scans were acquired using a single photon counting detector during the loading procedure. Individual tomographies were acquired within 120 seconds with a sample compression corresponding to 48 microns. The task was solved with the support of the Competence Center for High-Resolution 3D X-ray Imaging (ATCZ38) and Kompetenzzentrum MechanoBiologie in Regenerativer Medizin (ATCZ133) in cooperation with the Ludwig Boltzmann Gesellschaft - Institut für experimentelle und klinische Traumatologie and the University of Applied Sciences Upper Austria.

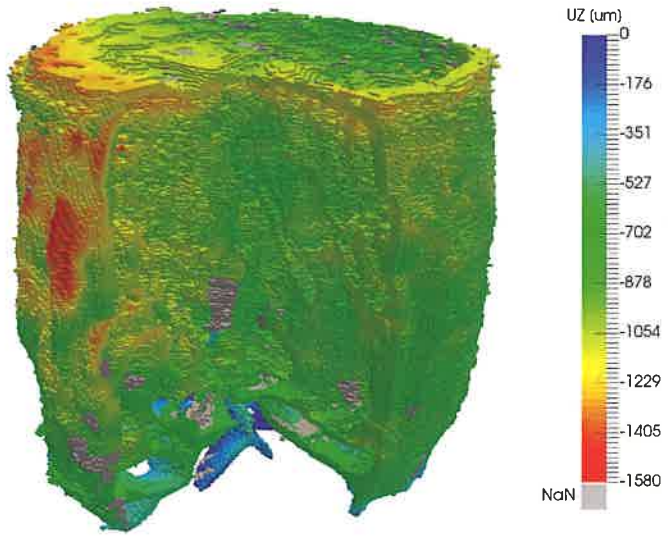


Figure: Visualisation of a deformed full-scale voxel model of the scaffold's microstructure showing displacements at the last load step

D. Kytýř, P. Zlámal

TOP MANAGEMENT OF THE CZECH ACADEMY OF SCIENCES VISITED ITAM

On Monday the 8th of February 2018, the president of the CAS, Prof. Eva Zažímalová, began her round of visits of the institutes of the CAS at ITAM. She had visited ITAM before, and this time she came with the vice-president, Prof. Jan Řídký, and two of the academy's board members, Lenka Vostrá and Pavel Krejčí. The visit started with a discussion with the management of ITAM, followed by tours of the Central Laboratory of Experimental Mechanics (CLEM), the Laboratory of Particular Media and the Laboratory of Biomechanics. At the end, the guests visited the newly built and inspected part of the institute.

B. Přechová

CET TEAM INVESTIGATES THE USE OF MEDIEVAL RUINS

In June of last year, the RUINS project supported by Interreg Central Europe was launched, with the CET team being one of 10 partners in an international consortium of 6 European countries. The aims of the project are to bring medieval ruins back to life using modern technical and economic approaches and to find ways to use them in contemporary societies while preserving their historical value. The project's output leads to these goals: the creation and distribution of internationally applicable manuals and procedures, including procedures for the modern administration and management of medieval ruins, particularly in Central Europe.

The project's activities also include surveys and case studies of six selected ruins. Immediately after the project was launched in June of last year, a field survey of Janowiec Castle in Poland was carried out, and then in August field surveys of the ruins of St. Stošije in Zadar (Croatia) and Šalek Castle in Velenje (Slovenia) followed. Since October, the CET team has been preparing for and securing research activities in the ruins of the fortified Bzovik Monastery in Slovakia and has conducted a technological workshop focused on in-situ diagnostic methods for historical wooden structures that took place in one of the monastery's bastions. In March of this year, a study visit was made to the city fortifications in Montagnana, Italy, and the Beatrice d'Este Villa with the remains of a medieval monastery. The output of study visits are always detailed reports mapping the history, current technical condition, conservation interventions and economic use of the given torsional objects. In the next phase of the project, the work will focus on creating manuals and implementing pilots on the selected ruins in Poland, Italy, Croatia, Slovenia and Slovakia.

More information about the project can be found at: http://www.interreg-central.eu/Content.Node/RUINS.html

The ruins of the fortified Bzovik Monastery in Slovakia

The ruins of St. Stošije in Zadar (Croatia)

J. Novotný

JIŘÍ NÁPRSTEK ELECTED CHAIRMAN OF THE CZECH SOCIETY OF MECHANICS

Ing. Jiří Náprstek, DrSc.

A secret election in January 2018 resulted in the appointment of a new committee head of the Czech Society of Mechanics (CSM). During a meeting on 7 February 2018, the new functionaries of the CSM were elected. Based on this vote, Ing. Jiří Náprstek, DrSc. from the Institute of Theoretical and Applied Mechanics of CAS was named the new chairman for the next four years.

More information about the domestic and international activities, management and history of the CSM can be found at: https://www.csm.cz.

MOBILITY OF RESEARCHERS AT CET

Each year the Center of Excellence Telč hosts several foreign researchers for short and long-term research stays. The year 2017 was not an exception. In March, Professor Rajesh Goyal head of the Institute of Engineering and Technology (India) came to work at the Climate Wind Tunnel Laboratory. In April, Karim Zara Zefreh from Antwerp University in Belgium participated in experiments in the Laboratory of X-ray Tomography. In the same laboratory, during two research stays, a metrology specialist from Belgium, Massimiliano Ferrucci, was involved in refining the setup of the unique Telč equipment. Yasemin Didem Aktas from University College London came to prepare larger future experiments in the climatic wind tunnel in May. In June, the Laboratory of Material Analysis and Microscopy hosted Professor Helois Nunes Bordall of the Danish University of Copenhagen. From late August to early September, Professor Piotr Gorski and his doctoral student, Marcin Tatara, conducted experiments in the climatic wind tunnel (both from the Opole University of Technology in Poland). In September and October, Dr. Andriy Buljac from the Croatian University of Zagreb co-operated on some other experiments.

Professor Bordall and Professor Goyal, in addition to conducting collaborative research, orally presented the results of their research to the staff of the Institute.

Four CET Ph.D. students were sent abroad for internships in 2017.

- Dita Machová studied at the University of Ljubljana from February to May 2017.
- Riccardo Cacciotti completed his internship in March and April 2017 at the International Center for the Study of the Preservation and Restoration of Cultural Property (ICCROM), Rome (Italy).
- Dita Frankeová did a month long internship (September - October) at the University of Padua (Italy).
- Klára Nedvědová started an internship at Donau University Krems (Austria) in December 2017.

J. Novotný

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newsletter

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Czech Academy of Sciences

ITAM ARCCHIP
INSTITUTE OF THEORETICAL AND APPLIED MECHANICS

1 / 2019

EDITORIAL

In editorial writing the "shorter is more difficult" rule applies. So this time it is a very difficult task for me to fit into these few lines. And the reason is that this time the contributors were very fruitful and filled up the designated area to the very last letter. Therefore only briefly.

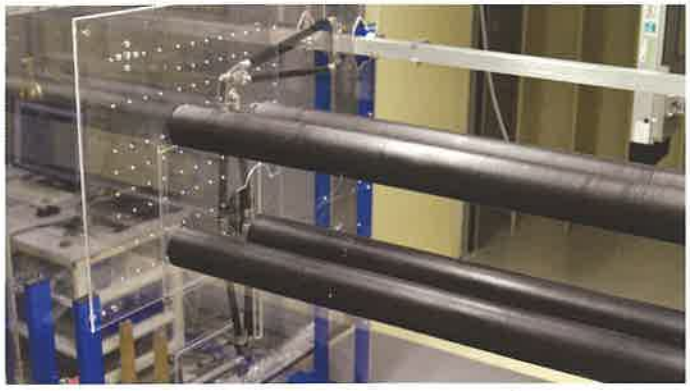
An interesting read is certainly the article on the aeroelastic stability of steel hangers, which was prepared by the Department of Dynamics and Aerodynamics. Furthermore, I must mention the interview with Dr Cyril Fischer, who runs the intern program in applied mathematics for high-school students within the Open Science project. And no less interesting is the view from the other side – that of the students themselves.

But now, I really have to conclude. Have a nice spring, summer and enjoyable read!

Stanislav Pospíšil, director

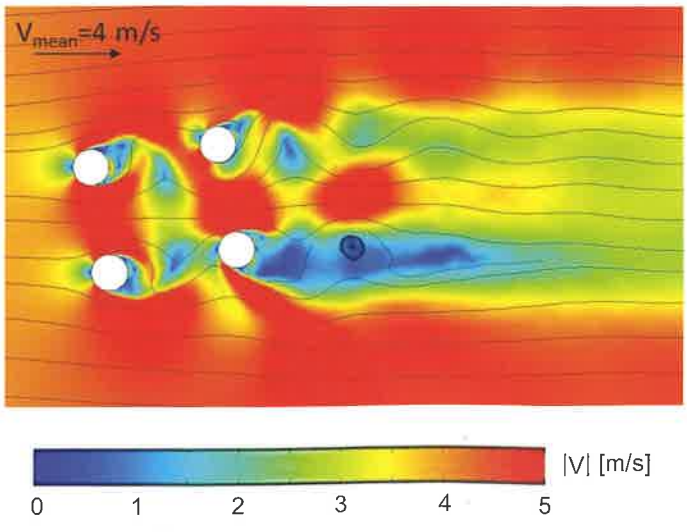
AEROELASTIC STABILITY OF FOUR HANGERS

Suspension rods (hangers) carrying the loads of bridges and roofs of large spans are generally slim, flexible and very low-damped structural elements. The combination of these properties and geometry allows for the formation of a physical phenomenon, even at normal wind speeds, where energy is drawn from the air stream for a relatively long period of time and converted into kinetic energy of the vibrating rod. Such vibrations usually have high vibration amplitudes and lead to significant fatigue stress and eventually to destruction of the entire hinge structure.



Aeroelastic model of four hangers placed in the wind tunnel

The aeroelastic behaviour of one hanger in the air stream is already a traditional task of building aerodynamics and aeroelasticity which we can solve. However, in the case of a pair, a trio or a larger group of rods placed in close proximity, there may be modifications to the case with a single rod, and here "all advice is valuable". The influence of the surrounding elements and the interaction with the current will begin to manifest, and thus a significant increase in load will occur. The pull rod placed in the winding creates a periodic vortex field that "hits" the rods placed in the wake, and this periodic load leads to oscillation of the elements that would not independently oscillate. The European standard dealing with wind loads on building structures addresses this phenomenon in a very simplified way. There are even known cases in which, despite the proposal realized under this regulation, undesirable rod vibrations have occurred. We are now conducting a detailed analysis of this phenomenon at our institute, which is examined both by numerical methods modelling the wind flow around vibrating rods and experimentally in a wind tunnel. From the results of calculations and experiments, we are able to predict the behaviour of the actual structure and take into account this interference phenomenon in the design of the structure.



Wind speed distribution for four hangers obtained by numerical simulation

M. Macháček

DOCUMENTATION OF MODERN ARCHITECTURE BY MODERN TECHNOLOGIES

BIM model of Ostrava-Vítkovice Railway Station visualized in the cloud service A360 by Autodesk

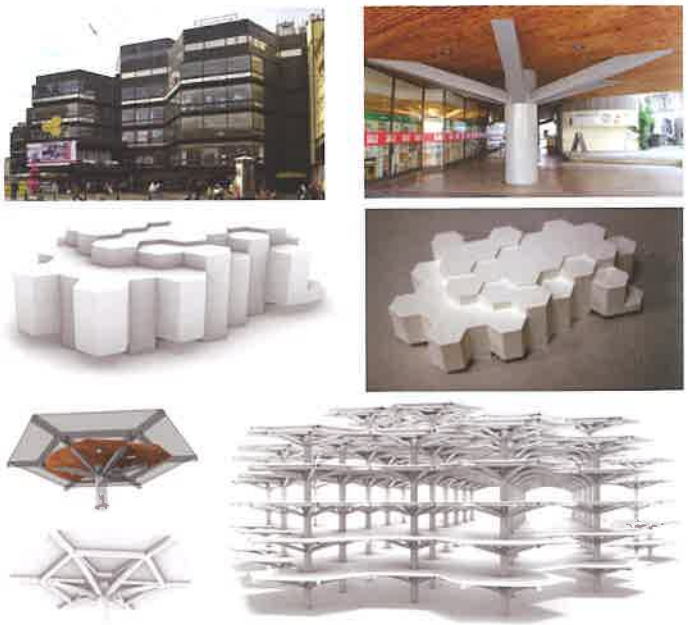
The topic of preservation of architecture from the 1960s and 1970s has recently gotten wider attention mostly due to planned or already realized demolitions of several objects (Transgas, Praha Hotel). Buildings from that period can disappear irretrievably, without society clarifying whether they (as cultural heritage) deserve to be protected or not. Therefore, the project "Analysis and presentation of the values of modern architecture of the 1960s and 1970s as part of the national and cultural identity of the Czech Republic" was initiated; supported by the Czech Ministry of Culture's NAKI program (2016-2020). ITAM CAS is one of the co-researchers of the project, which focuses on a deeper knowledge of buildings from the mentioned period and on defining the proper approach to their protection and reconstruction. Simultaneously, the project also studies options for documentation digitization and virtual preservation of buildings, whose authentic appearance, or even very existence, are endangered.

The webpage *www.ma6070.cz* is dedicated to the project. The first of the applied outputs achieved by ITAM CAS can be found there: a specialized map of the Ostrava-Vítkovice Railway Station including expert content created as a 3D dynamic model.

The digitization of cultural heritage is a rapidly developing field that utilizes the potential of modern technologies. The creation of authentic 3D models is one way of preserving valuable and unique monuments for future generations and, at the same time, of presenting them to the current one through the interactive online world. The BIM technology ("Building Information Modelling"), which enables the creation of information databases about buildings and their management during the buildings' lifetime, is used for the project works. Geometric data on the building in the form of a 3D model is part of the database. This technology is used nowadays mainly for project documentation of new buildings (part of the so called Industry 4.0), but lately it is being applied more and more abroad also on culture heritage as HBIM ("Historical/Heritage Building Information Modelling").

The data concerning the building geometry was, due to incomplete project documentation, collected with the help of photogrammetry, which is a fast and cheap method enabling the creation of a pointcloud that substitutes the classic data from surveying by e.g. laser scanning. The level of detail of the model is defined by its purpose. In the case of the Ostrava-Vítkovice Railway Station, the model is the combination of a structural model of the load-bearing elements made of reinforced concrete that is linked to the database of (not only) the material properties, and digital 3D mesh models of unique entities such as the watch tower from Vladimír Kopecký or decorative glass panels of banisters in the departure hall by František Burant and Benjamin Hejlek. Individual 3D models of the art are also presented on the "Sketchfab" server (sketchfab.com) in the profile MA6070 dedicated to the project.

Currently, the model of the Prior/Kotva Depertment Store (its heritage protection is a long lasting question), is being processed. The workflow is shown in Fig. 1. The study of building volumes emphasizes the architect's idea of the hexagon as a main geometrical structural element. In cases where the project documentation is missing or some of the elements are inaccessible (strut), the possibility to assess the dimensions from the photogrammetric pointcloud is advantageous (the column element). Thanks to 3D printing, the model can be easily shown in the real world again.



The digital documentation workflow: a volume model - from reality to 3D print (up), SCAN-to-BIM – pointcloud of the column from photogrammetry as a base for 3D modelling (bottom)

Project related publications:

Strakoš, M.; Anton, O.; Bydžovský, J.; Cikrle, P.; Černá, A. M.; Dufka, Á.; Hasníková, H.; Keršner, Z.; Kugl, J. - Kunecký, J.; Popelová, L.; Přendík, P.; Rotter, T.; Rovnaníková, P.; Šenberger, T.; Šimonová, H.; Urlich, P. Ostrava-Vítkovice Railway Station. History – architecture – heritage potential). Praha: Národní památkový ústav, 2017. 256 s. ISBN 978-80-87967-14-0.

Urlich, P.; Bydžovský, J.; Cikrle, P.; Hasníková, H.; Kunecký, J.; Moos, J.; Popelová, L.; Rovnaníková, P.; Sedláková, R.; Sedlmajer, M.; Šenberger, T.; Tryml, M. Prior/Kotva department store. History - architecture - heritage potential. Praha: Národní památkový ústav, České vysoké učení technické v Praze, 2018. 255 s. ISBN 978-80-87967-19-5.

H. Hasníková, K. Kulawiecová, J. Kunecký

WITH CYRIL FISCHER ABOUT OPEN SCIENCE INTERNSHIPS

For the second year in a row, Dr Cyril Fischer is running an internship intended for secondary school students within the Czech Academy of Sciences Open Science project. In this issue we bring you an interview with Cyril Fischer and his trainees: Anna Kneselová, Ondra Hamala, Adam Pazderka and Šimon Pekár. You can find the unabridged interviews at www.itam.cas.cz in the News section.

What motivated you to participate in Open Science project?
My children are of the same age as my students, near graduation. I can see that at eighteen they are too old for sitting in a classroom, school itself is not enjoyable for them. But I can sense in them a desire for „real information", something that will finally be useful, or at least that seems like it.

How do you come up with a topic?
It's hard to say in general. I think that a topic must be interesting and playful, but also difficult enough. It is optimal when a student comes to the edge of his/her abilities. It should be something that is not taught at school. And yet the topic must be broad enough because you never know who will be applying. Everyone has their edge somewhere else. So I try to bring myself back in time and imagine what might have interested me at that time.
Last year's topic had been prepared for a college student for a very long time as a bachelor thesis, but no one signed up at that time. It turned out pretty well this time however, the guys enjoyed it. They divided the tasks and wrote a nice program. This year I thought we could switch the roles. The seminars are led by the students, and I listen, learn and do the homework. I think this is a better concept.

How did you choose the trainees?
The propositions assume that the participants are selected based on motivation letters and CVs. But how do you choose when all the candidates are amazingly skilled and motivated? This year, I sent an intimidating exercise program to the enrolled candidates, hoping that some would give up. In vain.

B. Přechová, C Fischer

TRAINEES

Would you describe to me the topic of your internship? Why did you find this topic interesting?
Anna: I was interested in the topic because I knew from the title that it would be a challenge for me and very difficult. If I can persevere, I will gain a lot of new knowledge, which I would not otherwise get at my level of education.
Since I am also a laic regarding the subject matter, it is hard for me to simplify it. Mathematics has order, and things are given and defined in it. Using stochastic (random) processes, we try to simulate the real world and "translate" its chaotic form into a clear language that the mathematical tools offer.
Ondřej: The topic of our internship is not exactly defined, but we do mathematical tasks in Mathematica and Python, which will gradually introduce us to the solution of differential equations with random elements that need to be solved using computers. Because of its complexity it is analytically impossible.

How did you get involved in the Open Science internship?
Ondřej: I wanted to expand my knowledge in the field that interests me beyond the scope of schooling. And, if possible, under professional guidance. So when a friend told me about the Open Science Internships, I checked to see whether one of them would suit me.
Šimon: I attend a general high school and sometimes I have a problem with subjects that do not interest me. With subjects such as mathematics and physics I am hampered by the slow teaching of the subject matter. That's why it occurred to me to participate in Open Science, where I could gather interesting knowledge in those fields and develop my abilities.

Do you plan to pursue scientific work in the future?
Anna: In this respect, I still don't know what I want in the future. To practise science and discover new methods pushes the world forward. But it is always necessary to translate the theory into practice and launch a new idea so that it can be practically used. I would love to be a hybrid – to be able to do scientific work and at the same time put it into practice.
Adam: I feel quite motivated thanks to the internship and I like the academic environment. In the future I would rather focus on informatics, more precisely AI. But I don't know what research looks like in that field. As for physics and applied mechanics, I would definitely like it there.

Is there something you were afraid of before the internship? Has it become reality?
Anna: Yes, and again yes. I was afraid I wouldn't be able to keep up with the (for me) high level of mathematics. That happened, and it has been demanding hard work. Sometimes I am not able to absorb all the information. Despite that I am slowly moving forward.
Šimon: I was afraid I wouldn't understand it at all. I am the youngest of the interns, and I was worried because the topic is a huge leap into the unknown for me. Fortunately, my concern has only been partly realized.

Is this your first encounter with practical science?
Ondřej: Yes, for the first time I can see in detail what systematic scientific work looks like. So far, I have been to several lectures on school excursions that did not give me much.
Adam: I participated in an internship last year, so this is not my first encounter. In this internship I appreciate that it is both theoretical as well as practical. One really needs to know what one is doing to make it work.

How are these activities regarded by your teachers?
Šimon: My teachers are absolutely ok with it. There is no problem with notes, nor are the intern days included in my absence. Several times I have discussed the topic with a few of them and they have always tried to help me.
Adam: My school is very accommodating. Not only can I be absent once a month, but I don't have to do our yearly project and I can devote myself to the internship. I would like to add that it takes most of our free time, including weekends, so I wouldn't be able to manage it all anyway. I appreciate it.

The trainees with their lecturer Cyril Fischer

B. Přechová

KICK-OFF MEETING OF THE INTERNATIONAL PROJECT CONSECH20

CONSECH20 (CONSErvation of 20th century concrete Cultural Heritage in urban changing environments) is a 3-year JPICH international research project that aims to develop effective approaches for conservation and protection of 20th century heritage concrete buildings against ever-changing urban impacts, taking into account both technical and social aspects.
The kick-off meeting of CONSECH20 held on 14-15 February 2019 at ITAM, successfully brought together representatives from all five institutions from the CONSECH20 consortium: ITAM CAS, Delft University of Technology, University of Cyprus, University of Genoa and the Institute of Sociology of the National Academy of Sciences of Belarus, a total of 15 participants.
The main aim of the CONSECH20 meeting was to ensure that all the partners have a common understanding of the project and their respective roles in it. The meeting was an opportunity for all partners to establish closer relationships and present their prospective contribution to the project.

C. L. Nunes

UPCOMING EVENTS

On **5th and 6th June 2019** the **High-Resolution 3D X-ray Imaging Workshop** will take place at the University Centre Telč, summarizing the results of the Interreg ATCZ38 Com3d-XCT project. In addition to the participants of the project, foreign experts dealing with advanced X-ray imaging methods will be present at the workshop. Details of the event can be found at *http://xctw.itam.cas.cz/.*

After six years, the conference for students and young researchers, dealing mainly with experimental mechanics, returns to the Czech Republic. **The 17th Youth Symposium on Experimental Solid Mechanics** will take place at the University Centre Telč on **6-8th June 2019** under the auspices of IMEKO and with financial support of the CAS. Details can be found at the workshop website *http://ysesm2019.itam.cas.cz/.*

On **June 27th 2019**, ITAM CAS and the Municipal District Prague – Troja will host an **international conference on the topic „Managing the Protection of Cultural Heritage in a Changing Environment"**. The main objective of the event is to present the latest results of the Interreg CE ProteCHt2save project to stakeholders with emphasis on Czech experience and to present the issue from the perspective of managing cultural heritage protection in a changing environment. More information at: *www.interreg-central.eu/Content.Node/ProteCHt2save.html*

Interreg CENTRAL EUROPE ProteCHt2save

Interreg Österreich-Tschechische Republik Europäischer Fonds für regionale Entwicklung

D. Kytýř, B. Přechová

INTERNATIONAL WORKSHOP SCOLA TELCZ 2019

An international student workshop focusing on the former Jesuit College garden was held in Telč from February 22nd – 27th 2019. The aim this year was to design a solution for the garden space of the former Jesuit College, which today belongs to the Faculty of Civil Engineering of the CTU in Prague and is also adjacent to the building of the University Centre Telč of Masaryk University. The garden area, historically connected mainly with the operation of the Jesuit order in Telč, is located in the very centre of the city and represents a hidden and unused potential for the cultural life of the city.
The programme consisted of lectures by experts focused not only on the Jesuit order and its activities in Telč, but also on the principles of care for the UNESCO monument or city gardens at present. Central to the workshop was the collaboration of teams of students from different disciplines. The individual teams then tried to capture not only the history of the place, but also the needs of the contemporary city and its inhabitants, and introduce these in the form of a site-specific installation on the future use of the garden. The workshop was concluded in the late afternoon on Wednesday February 27th with the opening of the garden to the public and the presentation of student proposals along with the participation of representatives of Telč, individual universities and cooperating professional institutions.

J. Novotný

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ITAM ARCCHIP
INSTITUTE OF THEORETICAL AND APPLIED MECHANICS

Centre of Excellence Telč

2 / 2018

CONSERVATION OF 20TH CENTURY CONCRETE CULTURAL HERITAGE IN CHANGING URBAN ENVIRONMENTS

CONSECH20

CONSECH20 project proposed by ITAM CAS together with the Delft University of Technology (TUD), the University of Cyprus (UCY), the University of Genoa (UNIGE) and the Institute of Sociology of the National Academy of Sciences of Belarus (ISNAS) was amongst the 42 submitted proposals to the Joint Programming Initiative on Cultural Heritage call on the topic Heritage in Changing Environments. Out of these, 5 were recommended for funding, including the CONSECH20 proposal. CONSECH20 is a three year research project that aims to develop effective approaches for conservation and protection of 20th century heritage concrete buildings against the ever-changing urban impacts. 20th century concrete heritage is a major challenge for conservation both because of its remarkable architectural variety and experimental character in use of materials and technologies as well as due to the lack of recognition of its cultural and historical value by the general public. These aspects, together with the fast-changing urban environment, are leading causes of its deterioration and, sometimes, demolition. CONSECH20 focuses on structures built with early concrete (until 1960) of social interest in the sense of bringing people together (e.g. for recreation, inhabiting, working) to strengthen the link between society and 20th century architectural heritage. CONSECH20 will increase the potential of 20th century early concrete CH as a tool for social integration and cultural tourism and contribute to the establishment and development of the notion of Heritage Science, a relatively new and emerging field of science that aspires to bridge the gap between humanities and applied sciences. It will outline new approaches to participatory monitoring and conservation/restoration for future use of modern architectural heritage by stakeholders, and for citizen engagement in the protection of modern architectural heritage. The project will use representative case studies of early concrete buildings in four of the participating countries that can lead to the selection of appropriate evaluation and testing scenarios. ITAM CAS is the coordinating institution, and the project will start in January 2019.

C. Nunes

EDITORIAL

Dear readers and friends of science,
After a while we again hand you, this time for autumn evening reading under a lamp, another issue of the ITAM and CET Newsletter. Despite the summer holidays, the researchers from our departments have produced interesting results which are described in more detail on the following pages.
From the many results we can be proud of, I would like to mention the development of an effective method describing deformation processes and crack propagation in nonhomogeneous materials. Samples of the material are exposed to mechanical stress and irradiated at the same time. A unique device developed by ITAM employees has brought this method from theory into reality. ITAM research also has practical applications. A relatively complex analyses of a footbridge in Písek was carried out by scientists from the Department for Dynamics and Stochastic Mechanics. The footbridge consists of two different but connected bridges. The structure is therefore rather unusual and is characterised by a strong dynamic response to wind and pedestrian crossing on both parts.
In the text you can find e.g. a report on a prestigious award given to ITAM workers personally by the president of the Czech Academy of Sciences, Prof. Eva Zažímalová. It is a great honour, and we hope that this recognition will serve as inspiration to younger workers and proof that it is possible to attain high social prestige in the sciences. This is undoubtedly true of a former ITAM director Prof. Miroš Pirner, who turned 90 in September and is still scientifically active. We congratulate him on behalf of the editorial board of the Newsletter and ITAM workers.
ITAM and CET are present at conferences, abroad or with foreign guests. Before the summer we organised the international conference Engineering Mechanics 2018 in Svratka, and at the end of the summer we established a collaboration with The National Laboratory of Additive Manufacturing, 3D digitalization and Computed Tomography in Mexico. ITAM joined the international project Conservation of concrete Cultural Heritage (CONSECH20), and participated on the nineteenth annual Documentation and surveys of historical timber roofs course in Slovakia. In short, the summer and the beginning of autumn was again a very busy time at ITAM and CET.
I should probably stop listing our institute's activities though, as the editorial should not aspire to reveal everything. I wish you an entertaining read.

S. Pospíšil, director ÚTAM

PROF. PIRNER TURNS 90!

Prof. Ing. Miroš Pirner, DrSc., dr.h.c.

Prof. Miroš Pirner, former director of ITAM CAS, celebrated his 90th birthday this year. He served as director from 1990 to 1998. He lead the institute through the difficult period after 1989 when ITAM returned the Emmaus Monastery (where it had been located until then) to the Saint Benedict Order, and had to move to a new location. His expert and scientific work has been focused mainly on theoretical and experimental research of air flow effects on structures for which he received many awards. Currently Prof. Pirner serves as senior researcher in the department of Dynamics and Stochastic Mechanics. The ITAM collective wishes him all the best for the coming years!

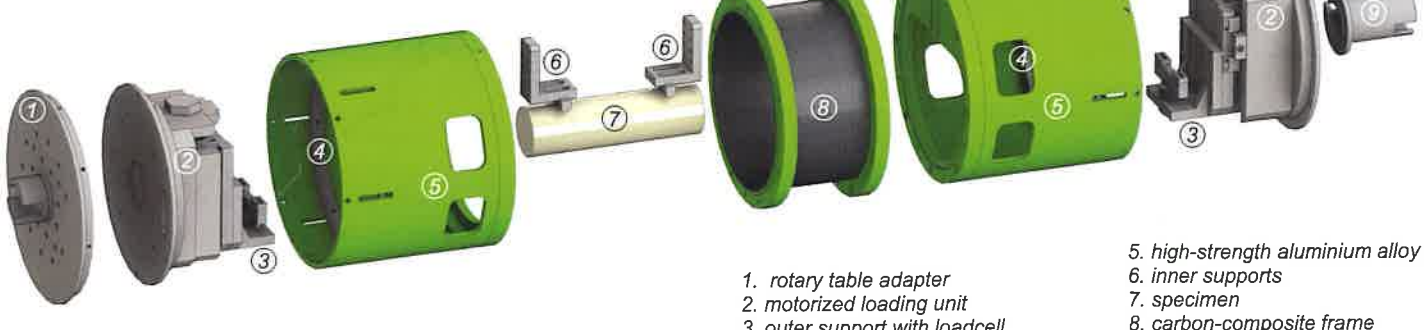
B. Přechová

FOUR-POINT BENDING TEST INSTRUMENTATION FOR 4D COMPUTED TOMOGRAPHY

High-resolution time-lapse micro-focus X-ray computed tomography (4D micro-CT) is a method for investigating the deformation processes and fracture propagation characteristics of non-homogeneous materials during loading.

For this purpose, a unique experimental device (patent pending PV2018-28) capable of four-point bending (4PB) testing during X-ray imaging has been developed. In contrast with standard bending setups, the proposed device is designed for vertical orientation of the investigated specimen, whose axis of rotation is identical to the rotational axis of the CT devices. The device is composed of three main components: a pair of a motorized loading units with integrated movable outer supports of the four-point bending arrangement, a pair of stationary inner supports of the four-point bending arrangement, and a cylindrical load bearing frame housing the loaded specimen together with the loading units and all the supports.

Proof of concept together with pilot experiments were successfully performed in the TORATOM CT scanner. Based on results acquired, fracture-process zone and macroscopic crack propagation in a quasi-brittle material can be observed in 3D using an in-situ loading procedure and high resolution 4D micro-CT.



Configuration of the 4PB loading device

1. *rotary table adapter*
2. *motorized loading unit*
3. *outer support with loadcell*
4. *docking ring*
5. *high-strength aluminium alloy frame*
6. *inner supports*
7. *specimen*
8. *carbon-composite frame*
9. *slip ring adapter*

P. Koudelka, D. Kytýř

SUMMER SCHOOL DOCUMENTATION AND SURVEYS OF HISTORICAL TIMBER ROOFS 2018

The 19th annual International Summer School, organized by the Czech Association of Construction Historians in collaboration with the CET, was held on September 10-14, 2018. This year, the territory of the southern part of Central Slovakia was chosen. The event was organised by our colleagues from the Monument Board of the Slovak Republics (Dr. Ľubor Suchý, Dr. Karol Ďurian). Thanks to the kind patronage of Prof. Pavel Gregor, Dean of the Faculty of Architecture of the STU in Bratislava, the participants could stay at the premises of the FASTU Educational and Scientific Research Centre in Banská Štiavnica. The course was attended by 21 participants from the Czech Republic, Slovakia and Romania. Other guests were also invited, especially the staff of the Regional Monument Office in Banská Bystrica and Banská Štiavnica. The program was focused on the practical aspects of study of historical roof trusses (on the recognition of features important for time and typological classification and so on). The participants got acquainted with regional features of traditional crafts, especially carpentry. The greatest impact was brought by a visit to the house at Štefan Moyzes Square No. 7 in the historical centre of Banská Bystrica. It is the only preserved roof with a unique chain structure made according to the patented design of Bedřich Schnirch from 1826. Very interesting were the evening lectures focused on methodological questions of surveys of roof trusses and their chronotypological division. Much appreciated was the presentation given by Boglárka Tóth about a state-of-the-art overview of dating results regarding timber roofs in Transylvania.

Inspection of the roof trusses of St. Lawrence Church church in Beluj, near B. Štiavnica

J. Bláha

COLLABORATION BETWEEN ITAM AND THE NATIONAL AUTONOMOUS UNIVERSITY OF MEXICO

ITAM CAS with its Telč centre established a research collaboration with Mexican partners. Assoc. Prof. Michal Vopálenský, Head of the X-ray Tomography Laboratory at CET, visited Mexico in April 2018, where he gave a speech at a conference on additive production and material characterisation. The conference was organised by The National Laboratory of Additive Manufacturing, 3D digitalization and Computed Tomography (MADiT) at the National Autonomous University of Mexico (UNAM). UNAM, with its more than 300 thousand students, is the largest university in Latin America, and on a world scale a very prestigious one. *"My presentation about the imaging possibilities we have in Telč, thanks to a unique patented tomograph TORATOM, met with a positive response, and I had a chance to talk to a number of Mexican scientists professing an interest in cooperation. Then it was only a question of finding a suitable collaboration platform and funding,"* says Vopálenský. It has been successful to a certain degree, and in July of this year Dr. Aida Rodiguez visited the Telč centre. She gave a lecture on modern additive production technologies, or 3D printing, for the purpose of bone implant preparation used especially in dental medicine. "*From September we agreed on a 6-week CET internship for a Mexican doctoral fellow, Adriana Hernandez from MADiT. She is working on characterisation of materials produced by 3D printing with help from ITAM biomechanics led by Dr. Kytýř. The results will be used in Adriana's doctoral thesis, and a scientific paper is also being prepared,*" adds Vopálenský.

From the left: G. Presbítero, L. Ruíz, A. Hernandéz, M. Vopálenský, A. Caballero

The last week of September saw the arrival of the Head of MADiT, Dr. Leopoldo Ruíz, and his deputy, Dr. Alberto Caballero. They brought with them a model of an artificial human oesophagus which can simulate the real one's functions. The TORATOM device in Telč was again used to monitor the passage of food through the organ, and now a paper is being prepared. In Prague, Dr. Ruíz gave an interest-arousing lecture, and the discussion that followed generated other possibilities for collaboration. *"I'm planning another trip to Mexico in December as I have been invited to participate in a meeting of European and Latin-American scientists working on the investigation of cultural heritage in relation to the European project E-RIHS (European Research Infrastructure for Heritage Science), to be presented in Brazil and Mexico,"* reveals Vopálenský. Since June, another alumni of UNAM, Dr. Gerardo Presbítero, has been investigating micro-fractures in bone tissue at the centre in Telč. As a part of a mobility project, he will be staying for 11 months. *"A collaboration with Latin America and especially with Mexico is something that I have always wanted to realize, owing also to my year-long stay at UNAM in 2003, but it had always been difficult to find a suitable framework. I think now we've managed that, and I just hope that the enthusiasm on both sides will last,"* concludes Vopálenský.

J. Novotný, M. Vopálenský

THE INTERNATIONAL CHEMISTRY OLYMPIAD AT SOLVAY'S QUARRY

The 50th International Chemistry Olympiad, IChO took place in Prague and Bratislava from the 19th to 29th of July, 2018. More than 300 talented students from 76 countries participated. As part of a daylong excursion they visited the open-air museum at Solvay's Quarry where Dr. Válek and his team gave a presentation on the history and evolution of lime production. The young chemists learned about limestone, the raw material used in the production of quicklime, its extraction and processing, the history of the industry, and the development of various types of inorganic binding agents. Contemporary research and projects were covered as well. As part of the lectures there were demonstrations on lime slaking, stirring and application. The young Olympians were captivated by the experiments, and eagerly asked numerous questions. The presentations for each group usually ended in lively discussions. For most of them this was the first time encountering a practical demonstration in the processing of quicklime. Thus the lectures and the program gave them insight into a craft that utilizes chemical processes they normally only study on a theoretical level.

Dr. Válek during a lecture for the participant of IChO 2018

P. Kozlovcev

ITAM TEAM GIVEN THE CZECH ACADEMY OF SCIENCES AWARD

Dr. Jiří Náprstek and Dr. Radomil Král received the Czech Academy of Sciences Award for their exceptional research, experimental development and innovation results in Theoretical background and implementation of finite element method for multi-dimensional Fokker-Planck equation analysis. The award ceremony took place on 16th October, 2018 at Villa Lanna in the presence of Academy Board representatives and the Scientific Board of the CAS, representatives of the press and other guests. Their work contributes exceptionally to the development of theoretical and numeric mechanics, and includes several original findings and methods which will set a new course for research focused on solving problems of stochastic dynamics and stability for the future.

Laureates of the Award with president of the CAS, Prof. Eva Zažímalová. Dr. Náprstek second row in the middle, Dr. Král behind him on the left.

Source: Czech Acad Sci / Photo: P. Jáchymová / B. Přechová

DYNAMIC LOADING TEST OF FOOTBRIDGES IN PÍSEK

At the end of September, a team from the Department for Dynamics and Stochastic Mechanics performed a dynamic loading test of two successive footbridges in Písek. The author of both of them – a cable-stayed one leading from the left bank of Otava river and a suspension one leading from the right bank – is architect Josef Pleskot. The aim of the test was to determine modal characteristics of the bridges and to compare them to a theoretical calculation done by a longstanding industrial partner of ITAM, EXCON company. A part of the test comprised a crossing of both bridge decks by several formations of pedestrians walking with various gait frequencies, which aimed to simulate norm-prescribed loading conditions and expected traffic. The comfort of pedestrians was then evaluated based on the detected bridge deck acceleration.

Footbridges in Písek during the dynamic loading test

S. Hračov

ENGINEERING MECHANICS 2018 CONFERENCE

The 24th annual international conference Engineering Mechanics 2018 took place from 14th to 17th of May, 2018 in Svratka. Organised by ITAM CAS, it is the main event of its kind in Czechia. More than 250 experts were present, both from the academic sphere and professionals. Participants from several European countries arrived to exchange their experience and knowledge regarding development of mechanics of solid and deformable objects, fluid mechanics and thermodynamics, especially in relation to projects investigated in Czechia and at cooperating universities around the world. The output is a printed open access book of conference proceedings with 242 contributions available at: *www.engmech.cz/im/proceedings/*.

Participants of the EM2018 Conference

B. Přechová, C. Fischer

A MORNING WITH PRAGUE GAS WORKS

PRAŽSKÁ PLYNÁRENSKÁ

On the 19th of September, 2018, ITAM CAS organised a Morning with Pražská plynárenská, a.s. (Prague Gas Works). After a brief excurse into the history of our institute, our guests from the gas distribution company heard about possible applications of our research activities in industry. They had the opportunity to view our Prague laboratories as well as observe a practical demonstration of an experiment related to a particular contract for a real pipe segment. The topics covered in the lively discussion during the morning were e.g. present and future cooperation, existing and potential research topics and various practical technical problems.

B. Přechová, M. Šperl

COLLABORATION OF SIX INSTITUTIONS FORMALISED IN TELČ BY MEMORANDUM

A ceremonial event of international importance took place on Friday 21st September, 2018 at University centre of Masaryk University in Telč – six academic institutions signed a Memorandum of Collaboration. They were represented by the President of the Danube University Krems, Friedrich Faulhammer, the Vice-chancellor of Masaryk University, Naděžda Rozehnalová, the Dean of Faculty of Architecture of STU in Bratislava, Pavel Gregor, the Dean of Civil Engineering Faculty of CTU in Prague, Jiří Máca, the President of the Czech National Heritage Institute Naděžda Goryczková, and the Director of CET, ITAM CAS Jakub Novotný. The document contains an agreement on exchange of empolyees, students, teacher collaboration, collaboration on scientific research, and the sharing of results of joint research.

On the Czech side, all the institutions have workplaces in Telč, and have been collaborating for several years, e.g. on realization of summer and winter schools called SCOLA TELCZ, attended by experts from the institutions and chosen university students.

The aim of the SCOLA TELCZ activity, is not only the strengthening of relationships between the institutions and the participants, but also an opinion exchange forum on different approaches and solutions to specific problems of cultural heritage preservation and conservation from the point of view of different scientific disciplines.

More information: *www.scola-telcz.net*

Signing of the memorandum

J. Novotný

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CET.ARCCHIP.CZ

CTU CZECH TECHNICAL UNIVERSITY IN PRAGUE

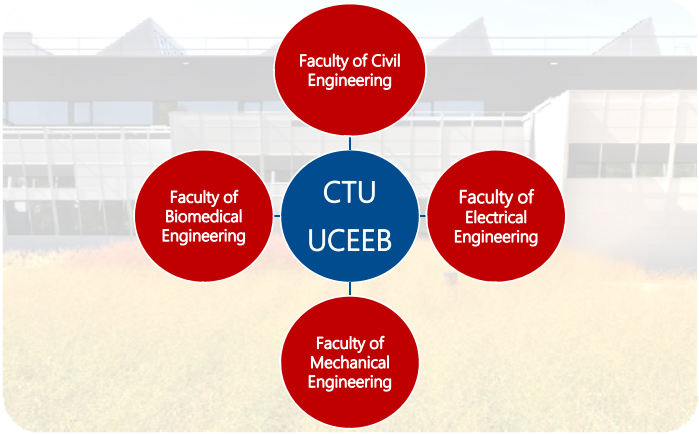
UCEEB UNIVERSITY CENTRE FOR ENERGY EFFICIENT BUILDINGS

UNIVERSITY CENTRE FOR ENERGY EFFICIENT BUILDINGS OF CTU

Research and Development for Sustainable Built Environment

PROFILE OF THE UNIVERSITY CENTRE

- The University Centre was established in 2012 as a stand - alone institute of the CTU in Prague
- It was established to streamline the cooperation between university and industry
- **Mission: By interconnecting new knowledge across disciplines, we contribute to the application of results of research and development that are beneficial for individuals, society and also environment.**
-



RESEARCH DEPARTMENTS

Director of CTU UCEEB

Assoc. Prof. Lukáš Ferkl

ARCHITECTURE AND ENVIRONMENT	ENERGY SYSTEMS OF BUILDINGS	INDOOR ENVIRONMENTAL QUALITY	MATERIALS AND STRUCTURE	CONTROL AND MONITORING OF INTELLIGENT BUILDINGS
				
Dr. Antonín Lupíšek	Assoc. Prof. Tomáš Matuška	Dr. Daniel Adamovský	Assoc. Prof. Petr Kuklík	Dr. Jan Včelák

MODERN LABORATORIES

- Acoustic laboratory
- Composite Constructions laboratory
- Laboratory of Construction Thermal Technics
- Sustainable construction laboratory
- Fire laboratory FireLAB
- Laboratory of Hydrometeorology and Hydropedology
- Energy laboratory LORCA
- Solar laboratory SOLAB²
- Laboratory of heat pumps
- Laboratory of indoor environment— climate double chambre, ventilation systems
- Laboratory of indoor environment— ventilation systems
- Laboratory of advanced biomaterials
- Laboratory of personalized telemedicine
- Mechanics laboratory
- Constructions engineering
- Material engineering
- Laboratory of electron microscopy
- Laboratory of electronic systems
- Laboratory of fibre optics
- Experimental battery repository
- Laboratory of photovoltaic systems and energetics

UCEEB MICROGRID

PROJECTS

- Horizon 2020
- Interreg Europe
- National projects
  - (TAČR, OP PIK, EUPRO II, MPO TRIO…)
- Projects active in 2017:
  - 30 grant projects
  - 170 projects of contractual research (55M CZK)

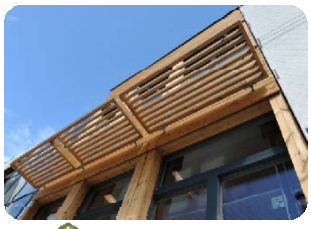
HORIZON 2020

Interreg Europe
European Union | European Regional Development Fund

EVROPSKÁ UNIE
Evropský fond pro regionální rozvoj
OP Podnikání a inovace pro konkurenceschopnost

T A
Č R
Technologická agentura České republiky

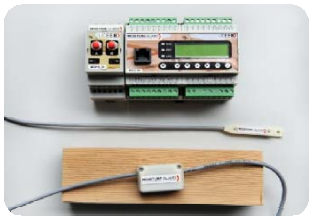
APPLIED TECHNOLOGIES



envilop

wave

SMART GLT
monitoring dřevěných konstrukcí



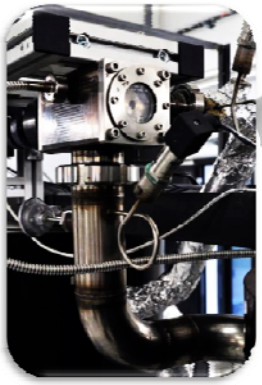
MOISTURE GUARD
systém pro kontinuální monitoring vlhkosti

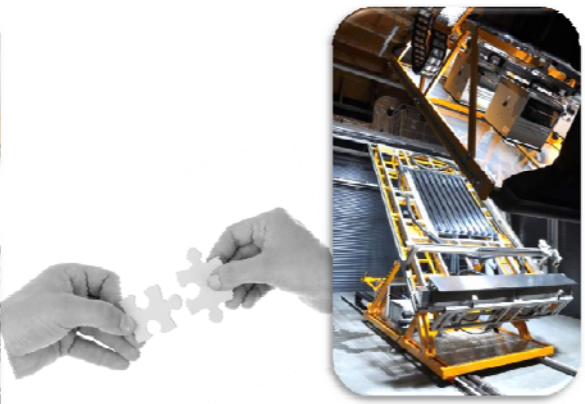
IoT

PV FORECAST

FORMS OF COOPERATION

- On-demand research and development
- Cooperation in research and development
- Testing and diagnostics
- Energy saving
- Optimization of operation
- Consultancy in the pre-project stage
- Assessment of projects and implementations
- Long-term monitoring of buildings
- Quality environment in buildings
- Studies for reconstructions of buildings
- Economical building operation
- Optimisation of energy purchase for communes
- Training courses for state administration
- and other





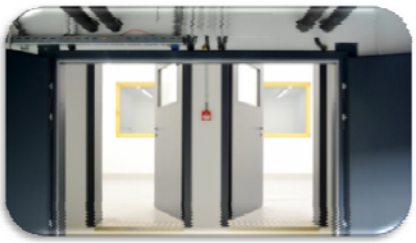
RP3 QUALITY OF INDOOR ENVIRONMENT

- **Introduction of RP3 Quality of indoor environment**
- **Laboratory of Indoor Environment**
  - Optimization of indoor environment in low and zero energy buildings with regard to occupant's health, comfort and productivity.
  - Team of 14 (5 seniors, 3 post-docs, 6 juniors)

- **Laboratory of Inteligent personal healthcare**
  - Development of personal health monitoring system.
  - Team of 4 (1 senior, 2 post-docs, 1 junior)

RP3 QUALITY OF INDOOR ENVIRONMENT

- **Laboratory equipment:**



Paralel test boots

Thermal manikin

Particle image velocimetry

Solar chimney

Test bed for domestic air handling units

REFERENCES – CONTRACTUAL RESEARCH

- Fenix Office Centre — Project controlling of the construction and the system for controlling and monitoring the operation of a passive building
- Expanding the capacity of the nursery and primary school of Ota Pavel in Buštěhrad
- Metrostav — green roof research
- Assistance for communes in projects — Dobříš, Postřekov, Podolanka, Kadaň, Slaný, Kladno, Prague 2, 3 and 7
- Air Navigation Services — air-conditioning of air traffic controller‘s stations
- Fraunhofer IWK — measurement of construction elements in double climate chamber
- Ha-Sec — significant increase of energy efficiency of the operation in the heavy mechanical engineering field using innovative approach

S.A.W.E.R.

Solar Air Water Earth Resource

Autonomous device cultivates dry desert into fertile land for crop cultivation.

- Preparation for the EXPO 2020 world exhibition in Dubai.
- UCEEB a Faculty of Mechanical Engineering, CTU in Prague: Development of technology for obtaining water from air.
- Institute of Botany of the Czech Academy of Sciences : Development of a system for desert cultivation.
- The device will produce average of 500 litres of water per day for keeping the green garden of 300 m^2 size.

MORE–CONNECT

CTU UCEEB AND RD RÝMAŘOV A. S.

- The goal of the project is to develop a solution advantageous from several points of view:
  - Prefabrication of individual elements will allow for cooperation of technology companies across Europe and also economic savings thanks to repeatability.
  - Possibility of choosing the reconstruction parameters in a „One-stop-shop“ online system with immediate information about the quality of the building and energy saving regarding the financial burden.
  - Prefabrication of the system and non-disturbing preparation works will significantly shorten the duration of the reconstruction. Expected construction works on site for reference objects are around 14 days, without the need to moving out of the object.

BUILDINGS IN HIGH ENERGY STANDARD

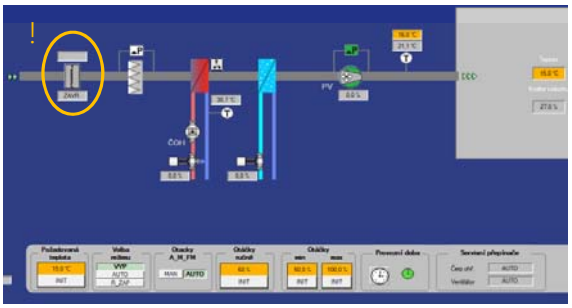
- We cultivate the building environment in Czech Republic using model projects.
- We promote high energy standards (nZEB, passive buildings).
- We are members of Netzwerk Effizienzhausplus led by Fraunhofer IBP.

Model project– library in Dobříš:

- very concrete and specific assignment
- until autumn 2018 DUR
- Hybrid GEOTABS system
  cooperation with Germany

FDD OF AIR-HANDLING UNITS

- Analysis of historical operation data stored in a control system.
- Search for faults in operation.
- Rule based analytical system.
- Energy and mass conservation, moist air processes.



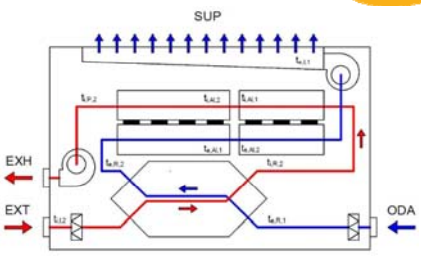
An example - closed inlet damper for 2 month in March and July 2015.
- Ventilation failed.
- Wasted approx. 12 779 kWh of electric energy.

Benefits:

- Savings of energy.
- Improving indoor environment quality.
- Decreasing service costs and extending AHU's lifetime.

LOCAL AIR HANDLING UNIT WITH TEM

- Experimentally proved practical usability of a ventilation unit with thermoelectric heat exchanger.
- Local availability of supply air heating and cooling together with ventilation.
- Supply air temp. for heating up to 35 °C ($t_e \leq 0$ °C), for cooling down to 18 °C (at t_e = 35 °C).
- At 50 m^3/h cooling output up to 200 W (EER 1 up to 6), heating output up to 700 W (COP 2,5 up to 20) – entire local AHU.



CTU
CZECH TECHNICAL UNIVERSITY IN PRAGUE

UCEEB
UNIVERSITY CENTRE FOR ENERGY EFFICIENT BUILDINGS

MANY THANKS FOR YOUR ATTENTION

University Centre for Energy Efficient Buildings of the CTU

Třinecká 1024, 273 43 Buštěhrad

www.uceeb.cz | info@uceeb.cz

Primary Activities of the Laboratory

- Complete material analysis/ determination of the morphology of the surface, morphology of particles and chemical composition, determination of the crystal structure of materials
- Preparation of samples for optical and electron microscopy (the transmission one as well as the scanning one)
- Qualitative and quantitative analysis of the chemical composition of samples using X-ray microanalysis (EDS/ WDS)
- Determination of crystal orientation and phase composition of materials using EBSD
- 3D model of the surface using electron microscope
- Measuring using the polarizing microscope in direct as well as reflected light

University Centre for Energy Efficient Buildings CTU in Prague

- The aim of the Centre is to promote energy efficient and environmentally friendly buildings that are comfortable for their users.

Třinecká 1024,
273 43 Buštěhrad,
Czech Republic
microscopy@uceeb.cz
+420 224 354 758
+420 224 356 741

UCEEB)

Laboratory of Electron Microscopy and Microanalysis

附錄3 捷克UCEEB實驗室型錄

Detailed micro-/nano-analysis of various types of materials

MERLIN

CTU

UCEEB

About the Laboratory

The Laboratory of Electron Microscopy and Microanalysis is equipped completely for the preparation of samples for electron as well as optical microscopy. The laboratory is focused on the investigation of topology, morphology, chemical, structural and phase composition of materials resp. on determining their crystal orientation. Many scientific-research activities take place here within the scope of the cooperation with the academic sphere and with industry.

Technical parameters of FEG SEM Merlin ZEISS

Source of electrons:	Schottky cathode
Accelerating voltage:	500 V up to 30 kV
Magnification:	12× up to 2,000,000×
Current of the probe:	10 pA up to 300 nA
Working distance:	1 up to 50 mm
Sample size:	diameter up to 330 mm, height up to 270 mm
Rotation in plane:	360°
Inclination of the sample:	−3° up to +60°

Instrumentation

Electron microscopy:

- Scanning electron microscope with the Schottky cathode FEG SEM Merlin
- Energy-dispersive spectrometer (EDS)
- Wavelength-dispersive spectrometer (WDS)
- Electron backscatter diffraction (EBSD)
- Scanning transmission detector (STEM)

Light microscopy:

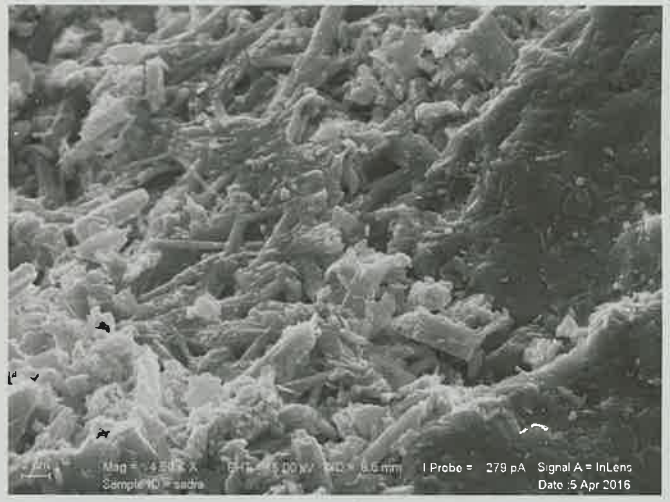
- Microscope with a transfocator and the possibility of 3D imaging
- Polarizing microscope

Complete equipment for the preparation of samples:

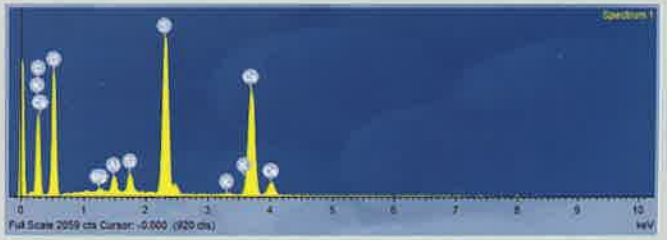
- Precision dividing saw, lapping machine, automatic metallographic grinder, vacuum chamber for degassing the samples, electrolytic polisher, ionic polisher
- Device for the application of thin layers (carbon, gold)

References

In the scope of cooperation with the CTU, analysis of the structure of cement binding agents was carried out. Besides the structure of the cement putty itself, the influence of various additives on the final hydrating products in the binding agent is analyzed as well. Together with the RUUKKI company, a study of welded joints of steel was processed. Using the electron and light microscopy, the research of glass fibers was carried out. In cooperation with the University of Warsaw, material research of old binding mixtures and plasters from the area of southern Egypt and northern Sudan takes place.



Study of the morphology of gypsum crystals at the surface of aggregate



EDS spectrum of gypsum crystal at the surface of aggregate

Primary Activities of the Laboratory

- Design of electronic circuits
- Development of sensors and sensor systems
- Programming of built-in systems
- Development of user applications
- Programming of controlling systems
- Mechanical design
- 3D printing
- Design and production of printed circuit boards

University Centre for Energy Efficient Buildings CTU in Prague

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Třinecká 1024,
273 43 Buštěhrad,
Czech Republic
electronics@uceeb.cz
+420 224 356 753
+420 224 356 751

UCEEB

Laboratory of Electronic Systems

Development, implementation and tests of electronic components and systems

CTU

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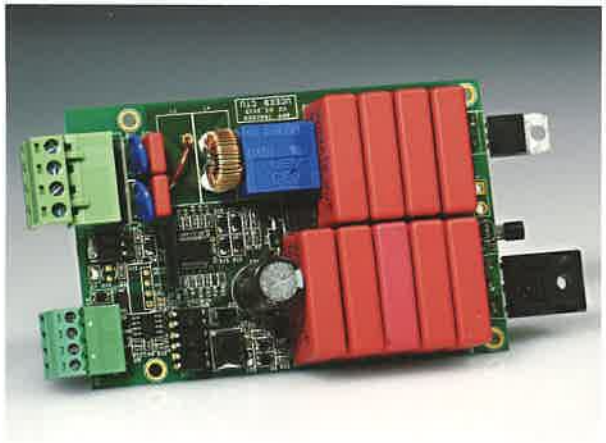
About the Laboratory

The Laboratory of Electronic Systems is equipped for the development and testing of products from the stage of development of electronics to mechanical design, development of firmware and software to testing itself. The subjects of interests are primarily sensors and sensor systems that can be used in buildings. The laboratory equipment allows to carry out magnetic and thermal simulations.

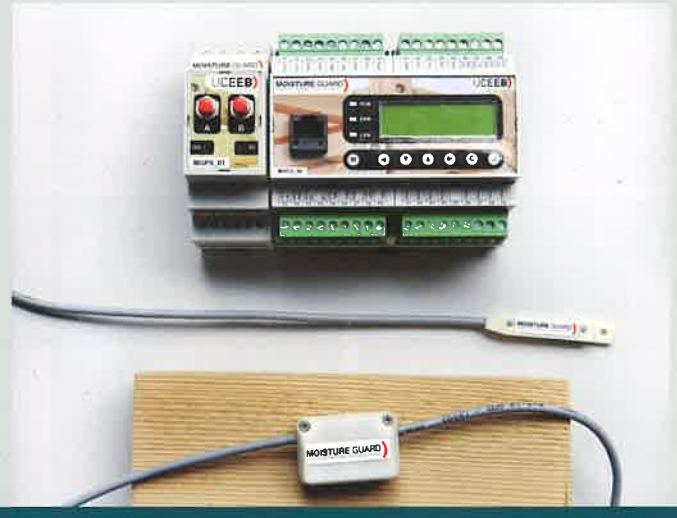


Instrumentation

- Electronic devices – power sources, oscilloscopes, spectral analyzer, measuring systems, soldering workplace
- Diagnostic systems – thermal camera, endoscopic camera, precise accelerometers, laser measurers, magnetometers and metal detectors
- 3D printing center FORTUS 400mc – quick production of prototypes, modeling space of 406 × 355 × 406 mm, resolution up to 0.127 mm, materials ABS-M30, PC-ABS, PC, PC-ISO, ULTEM

Example of Laboratory Measuring

- System for continuous monitoring of moisture in wooden structures Moisture Guard was developed in the laboratory.
- DC-DC inverters for the Sunriver solar yacht were developed on demand.
- Based on simulations, magnetic circuits of metal separator were optimized.
- Electronics for underground navigation of drilling rigs for underground horizontal drilling are developed in the laboratory. This navigation is based on the principle of generating the magnetic field of known parameters and its recording using precise magnetic sensors.
- The newest product of the laboratory is the combined sensor for measuring the quality of the inside environment. It is capable of measuring the temperature, relative humidity, concentration of carbon dioxide (CO_2) and concentration of volatile organic compounds (VOC).



Primary Activities of the Laboratory

- Development of carriers based on nanofibers, polymeric foams, hydrogels and their composites for biomedical and technical purposes
- Polymer applications for technical and biomedical purposes
- Characterization and production of intelligent micro- and nano-coatings and systems
- Nanofiber layers with thermal-acoustic insulation properties
- Preparation of composite carriers and medical devices for tissue engineering

The laboratory offers accredited tests

- Determination of structural surface morphology of nanofibers using the scanning electron microscopy method
- Determination of glyoxal using the photometric method

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Třinecká 1024,
273 43 Buštěhrad,
Czech Republic
biomaterials@uceeb.cz
+420 257 296 350
+420 608 979 660

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Laboratory of Advanced Biomaterials

Development of new nanomaterials for biomedical and technical purposes

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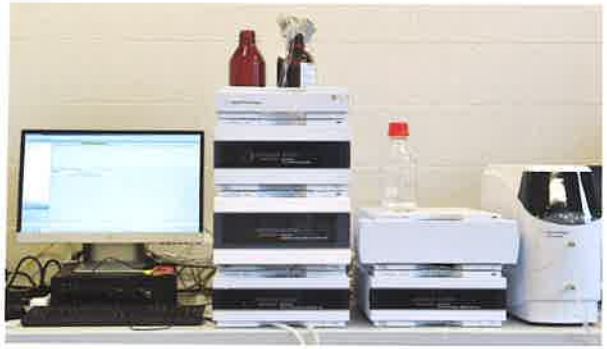

About the Laboratory

The Laboratory of Advanced Biomaterials is used for the preparation of nanofiber materials using electrostatic and centrifugal fiber spinning, microparticles using cryogenic grinding and ultrasound atomization as well as for the preparation of liposomes. Moreover, it offers other top technologies used for the characterization of physical-chemical properties of pharmacological and biological materials.

Activities of the Laboratory

- Testing the preparation of nanofiber material from solutions with different ratios of bio-active materials
- Characterization of properties of material prepared using the SEM microscope
- Development of new nano-materials for biomedical (medical devices, tissue engineering, controlled delivery of medicaments) and technical purposes (construction and safety, thin films)
- Production of innovated electrodes for electrostatic fiber spinning
- Study of testing of fiber spinning from polymeric solutions
- Determination of mechanical properties of nanofiber composite

Instrumentation

- Thermal field emission scanning electron microscope VEGA 3 SBU
- Lyophilizer BenchTop Pro XL 8L by SP Scientific
- MultiSpin STS 1402
- Forcespinner Cyclone™ L–1000M/D by Fiberio
- Laser diffraction MASTERSIZER 3000 by Malvern with low-volume dispersion automated unit Hydro MV

Examples of Carried-Out Cooperation on Projects

In the Laboratory of Advanced Biomaterials, 3D nanofiber carrier with incorporated system of controlled delivery of medicaments for tissue engineering of bone and cartilage is developed. Furthermore, functionalized nanofibers for collection, identification and long-term storage of scents are developed here.

- Determination of morphological properties of polymers, fabrics, cement, metal pulvers and zircon as well as characterization of some biological materials
- Measuring of particle size using laser diffraction (method of wet measuring)
- Determination of liposome size and of polymeric nano- and micro-particle size
- Lyofilization of samples

References

- Risk of condensation in an aluminum windows frame in winter conditions with overpressure from the interior side (Schüco International KG)
- Hygrothermal behavior of windows in masonry wall with ETICS in winter conditions with overpressure from the interior side and at wind-driven rain from the exterior side (PKS Okna a. s.)
- Airtightness of constructions of sloped roofs with thermal-insulating fill of sprayed PU foam (LIKOS a. s.)

Large Climatic Double Chamber

Complex climatic tests of building components and elements

Hygrothermal Laboratory

University Centre for Energy Efficient Buildings CTU in Prague

- The aim of the Centre is to promote energy efficient and environmentally friendly buildings that are comfortable for their users.

Třinecká 1024,
273 43 Buštěhrad,
Czech Republic
Ing. Kamil Stanek, Ph.D.
hygrothermal.laboratory@uceeb.cz
+420 224 356 711
+420 778 411 622

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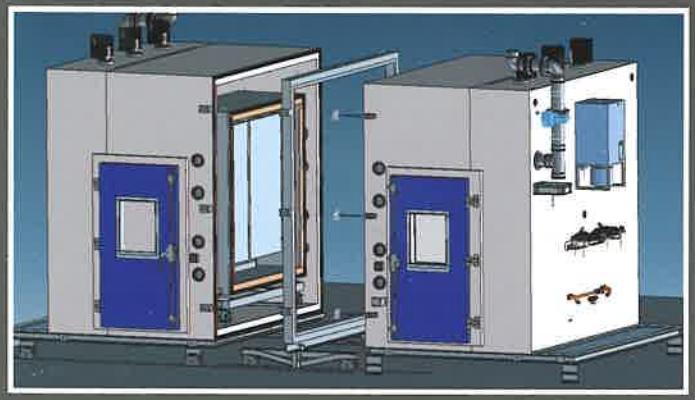
Basic Information

The purpose of the large climatic double chamber is to evaluate the behavior of building components and elements in the full scale when exposed to complex climatic conditions on both sides.



Testing Device

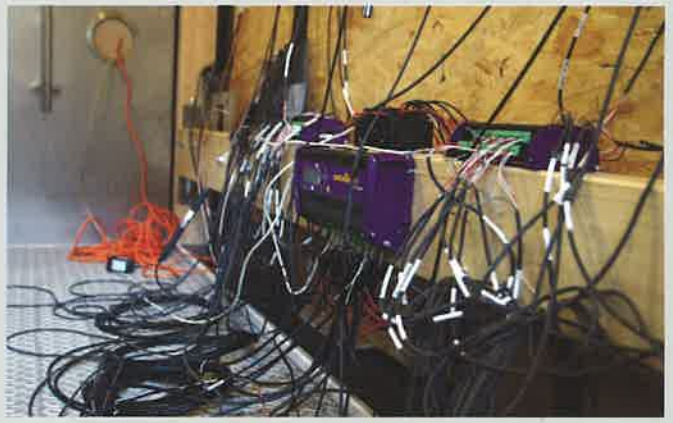
The climatic double chamber allows for testing the samples with dimensions up to 3.0 x 3.0 m. The sample is installed into the testing frame and placed between the Outdoor and Indoor chamber where both chambers allow for precise regulation of temperature and relative humidity as well as the pressure difference between the chambers. Furthermore, the Outdoor chamber can be equipped with solar and rain simulator and the Indoor chamber with a Hotbox (device for measuring the thermal transmittance).

- Parameter Outdoor chamber Indoor chamber
- Inner dimensions 3.0 x 3.0 x 1.5 m 3.0 x 3.0 x 1.5 m
- Temperature range –20 to +80 °C –10 to +60 °C
- Relative humidity range 10 to 95% 10 to 95%
- Rate of temperature change 1 K/min 1 K/min
- Overpressure up to 300 Pa up to 300 Pa
- Additional equipment of the chamber
- Solar simulator
- Rain simulator
- Device for measuring the air permeability
- Hotbox (measuring the U-values)
- Device for measuring the diffusion of water vapor
- Device for measuring the air permeability

Testing and measurement options

Thanks to the integrated control system, short-term as well as long-term tests can be performed under various climatic conditions. The variability of settings allows for wide range of testing options from one-parameter steady-state tests to complex dynamic tests.

The tested sample can be equipped with sensors of temperature, relative humidity, heat flux and moisture content (Rotronic, Hukseflux, Sensit, Elbez). The surface of the tested sample can be monitored with a hi-res infrared camera (Infratec). Measured data is recorded during the whole test and their online presentation is also available.



Jsme členem

Evropská aliance pro energetický výzkum, společný program Smart Cities

Česká rada pro šetrné budovy

Czech Smart City Cluster

Asociace poskytovatelů energetických služeb

Platforma pro energeticky efektivní výstavbu

Univerzitní centrum energeticky efektivních budov ČVUT v Praze

- Cílem centra je komplexně pomáhat vzniku staveb, které jsou energeticky efektivní, přátelské k životnímu prostředí a svým obyvatelům poskytují patřičný komfort.

Kontakt:
Třinecká 1024,
273 43 Buštěhrad
Ing. Mgr. Michal Kuzmič
michal.kuzmic@cvut.cz
+420 773 070 447

UCEEB

Smart City

Odborná podpora obcí při zavádění technologických inovací

ČVUT

UCEEB

O službě

Cesta ke Smart City vyžaduje funkční spolupráci obce s výzkumným sektorem. ČVUT UCEEB je výzkumné centrum zaměřené na energetiku a rozvoj udržitelné výstavby. Našimi partnery jsou samosprávy, soukromí investoři a neziskové organizace.

Poskytujeme

- odbornou podporu obcím při zavádění nových technologií
- návrh koncepčního rozvoje Smart City, chytré energetiky, řešení pro domácí péči, integrované elektromobility a internetu věcí
- zpracování nezávislých studií a vývoj technologií na základě konkrétních potřeb obce

Typy služeb

- návrhy a posouzení technologických investic na úrovni obce jako celku, veřejných prostranství i konkrétních budov
- příprava koncepčních dokumentů Smart City
- vzdělávání zástupců municipalit
- zapojení uživatelů technologií ve fázi návrhu i provozu

Smart City je přístup k rozvoji města, který městu umožňuje zvýšit kvalitu života občanům pomocí nových technologií a organizačních inovací.

Kompetence ČVUT UCEEB

- urbanistický rozvoj území
- kvalita architektonického a stavebního řešení
- plánování energetických zdrojů
- lokální řízení výroby, ukládání a spotřeby energie
- elektromobilita integrovaná do městské energetiky
- sledování a řízení kvality prostředí v budovách
- systémy pro dálkový monitoring spotřeb a vybraných parametrů (internet věcí)
- technologie pro seniory a uživatele se speciálními potřebami

Reference

Praha 3
Koncepce Praha 3 na cestě ke Smart City: Městská část oceněna titulem Chytrá města pro budoucnost 2017.

Kroměříž
Koncepce podpory obnovitelných zdrojů: návrh způsobu podpory obnovitelných zdrojů pro občany, pro snížení závislosti města na fosilních palivech.

Praha 2
Chytrá energetika pro Prahu 2: koncepce systematického řízení energetiky městské části.

Kladno
Platforma pro monitoring prostředí ve školách: platforma internetu věcí pro dálkový monitoring vnitřního prostředí v kladenských základních školách.

Praha 7
Studie proveditelnosti Smart Home Care: návrh technologií v integrované péči pro Prahu 7, který umožní seniorům déle zůstat v domácím prostředí.

R&D Departments

Architecture and the Environment

Environmetally friendly, safe and comfortable buildings

Energy Systems of Buildings

Comprehensive focus on energy savings, energy sources optimization and renewable energy sources utilization

Indoor Environmental Quality

Research and development of systems improving the quality and comfort of the indoor environment in energy efficient buildings

Materials and Structures

Advanced tests of mechanical properties of materials, building elements and components

Control and Monitoring of Intelligent Buildings

Design of advanced algorithms to control building energy systems, development of new sensors to monitor indoor environment and construction

University Centre for Energy Efficient Buildings CTU in Prague

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Třinecká 1024,
273 43 Buštěhrad,
Czech Republic
info@uceeb.cz
+420 778 736 908
+420 224 356 701

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University Centre for Energy Efficient Buildings

Research institute dedicated to sustainable building

CTU

UCEEB

University Centre for Energy Efficient Buildings

- Associates the experts from Czech Technical University in Prague dealing with sustainable buildings
- Facilitates university and industry cooperation, focuses on the commercialization of research results and technology transfer
- Develops, innovates and offers original solutions for sustainable buildings throughout their life cycle, healthy indoor environment, operating and energy costs

UCEEB multidisciplinary team covers complex research and development

- Unique experimental facility, enabling complex testing of components, construction elements and technologies
- The unique equipment and diversity of lab facilities offer local and foreign students and companies an opportunity to use the laboratories and the equipment for complex evaluation of materials and prototyping

Laboratories

Acoustic Laboratory
Composite Constructions Laboratory
Sustainable Construction Laboratory
Fire Laboratory FireLAB
Laboratory of Hydrometeorology and Hydropedology
Hygrothermal Laboratory

Energy Laboratory LORCA
Solar Laboratory SOLAB²
Laboratory of Heat Pumps

Laboratory of Indoor Environment – Climate Double Chamber, Ventilation Systems
Laboratory of Advanced Biomaterials
Laboratory of Personalized Telemedicine

Mechanical Test Laboratory
Structural Engineering
Material Engineering
Laboratory of Electron Microscopy

Laboratory of Electronic Systems
Fibre Optic Laboratory
Experimental Battery Storage
Laboratory of Photovoltaic Systems and Energy

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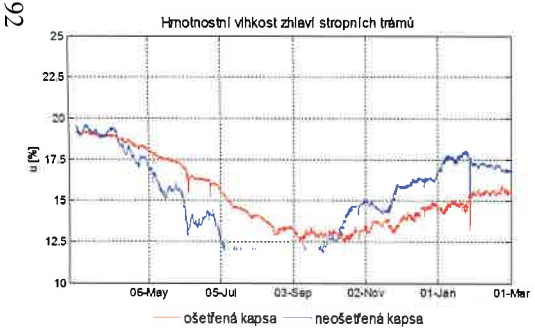
Laboratory of Photovoltaic Systems and Energy

Primary Activities of the Laboratory

The primary aim is to obtain high-quality and complete long-term data of the hygro-thermal behaviour of building envelope structures. Typical testing of samples takes place during one year-long cycle at mini-mum, during which detailed monitoring is carried out using as many as hundreds of sensors.

Measuring can be carried out on exterior walls or light curtain walls of any composi-tion resp. on compositions of pitched roofs including openings. Measured data are recorded and processed automatically and their evaluation is carried out in the form of an expert report or an on-line presentation.



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Třinecká 1024,
273 43 Buštěhrad,
Czech Republic
hygrothermal.laboratory@uceeb.cz
+420 224 357 174

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Experimental Facade

Long-term monitoring of hygrothermal behaviour of building constructions

Hygrothermal Laboratory

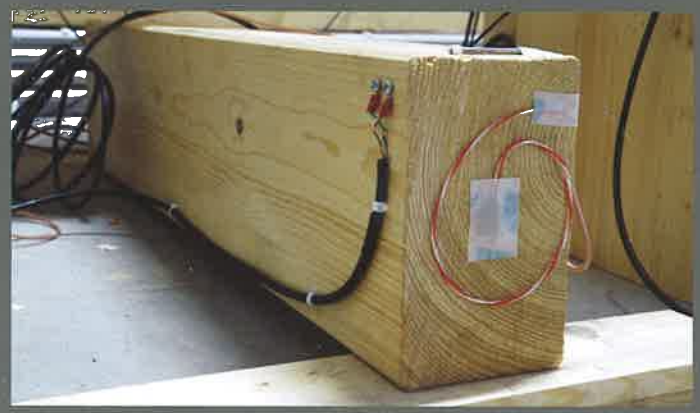
CTU

UCEEB

About the Laboratory

The experimental facade consists of six testing fields of 3.2 by 3.0 m facing westwards. These can be stocked with segments of building envelopes. The fields can be further divided into smaller areas, allowing to test higher numbers of samples. The stocked samples are exposed to natural exterior environment from the outside and to controlled interior environment from the inside.

The laboratory complements other kinds of experiments including in-situ measurements or testing in climatic chambers.



Carried-Out Measuring

During the assembly or production, the samples are equipped with sensors according to the requests of the customer (more than 700 usable sensors, 24 monitored parameters per sample).

Measured properties of the interior environment

- temperature and relative air humidity
- pressure difference between the exterior and the interior

Measured properties by the sample

- temperature and relative air humidity on the surface and within the sample
- heat flux
- moisture content of the material

Measured properties of the external environment

- temperature and relative air humidity
- solar irradiance
- long-wave radiation
- wind speed
- air flow velocity in ventilated cavities
- wind-driven rain

References

Currently, eight samples of modern wooden structures produced by the PENATUS company are being measured. Comparisons of compositions with ventilated facade and non-ventilated system, various construction and material systems, and diffusion-open as well as closed compositions are carried out.

Three systems for internal thermal insulation of historical brick buildings including various adaptations of pockets for beam headers are being measured in cooperation with the Ciur, ISOVER and Va-q-tec companies.

Furthermore, a curtain wall Envilop which is based on wood (www.uceeb.cz/envilop) and walls made of load bearing straw with clay plasters are measured long term.

Main Activities of the Laboratory

- For architects and developers, we offer analyses, optimization and professional consultations leading to the improvement of construction projects performance
- We offer contractual research in the area of environmental impact of building materials, constructions and buildings
- We provide professional support for contract owners for new buildings and reconstructions of green buildings
- We consult and process energy concepts of cities and villages
- We collaborate on the creation of strategies of smart cities and villages development

SBToolCZ

University Centre for Energy Efficient Buildings CTU in Prague

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Třinecká 1024,
273 43 Buštěhrad,
Czech Republic
Ing. Antonin Lupisek, Ph.D.
sustainability@uceeb.cz
+420 777 215 770

UCEEB

Sustainable Building Laboratory

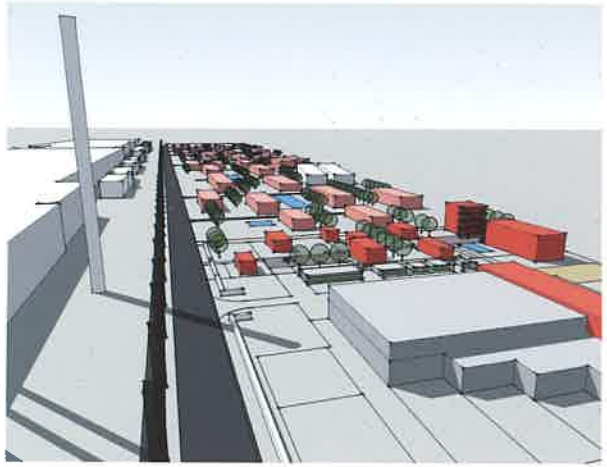
Design, optimization and certification of green buildings

CTU

UCEEB

About the Laboratory

The laboratory deals with the problems of sustainable construction during the whole life cycle. It offers a new approach to design, construction and operation of buildings and urban districts so that they fulfill a wide range of functional, economical, environmental, social and cultural demands. We guide the investors of new buildings and reconstructions of green buildings through the process of creation of the project specification.



Instrumentation

- Software for life cycle modelling (SimaPro)
- Access to databases of environmental impact of materials and products (Ecoinvent)
- Custom tools for evaluating and certification of the environmental impact of constructions and buildings (SBToolCZ and others)

SimaPro

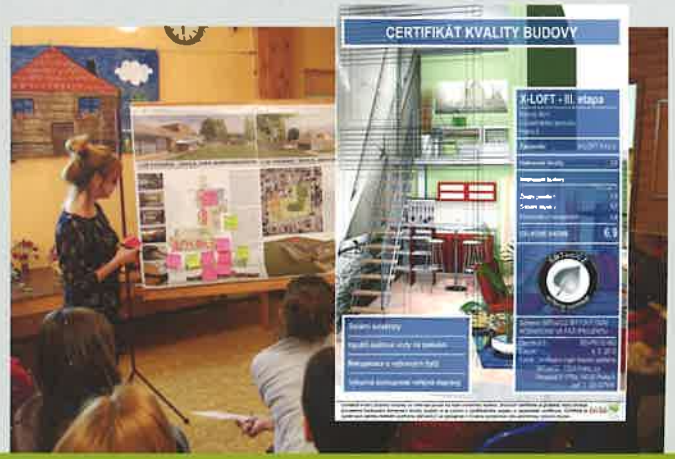
ecoinvent

Areas of Expertise

- Concept of green buildings and urban complexes
- Environmental impacts of the construction industry
- Complex evaluation of building quality
- Life cycle assessment of constructional elements and buildings
- Assessment of the life cycle of construction elements and buildings
- Support of green public procurement in construction (GPP)
- Corporate social responsibility (CSR) – consultancy in the area of reducing the environmental impact of building stock and technologies
- Consultancy in the area of legislation in energy and environment in the construction industry of the EU
- Trainings and consultancy in the area of green building
- Circulatory economy and recycling in the construction industry

References

- Development and professional guarantee of the SBToolCZ certification system (www.sbtool.cz)
- Study for reducing the environmental impact of the Ministry of Labour and Social Affairs of the Czech Republic based on the principle of life cycle assessment
- Participation in the Airhouse team at the U.S. Solar Decathlon 2013 competition
- Carbon footprint in the construction industry – research of tools and approaches in the EU
- Analysis of the Czech, German and Austrian legislation related to the energy demands of buildings
- Proposal of complex retrofit of a primary school, management of participation groups with users for the town of Buštěhrad
- Proposal of a hybrid autonomous energy system of the Březník object for the Šumava national park
- Professional partnership of the Czech Off-Grid Houses contest
- Creation of the Smart City concept for the Prague 3 municipality



Main Activities of the Laboratory

- Measuring of hygrothermal characteristics of building materials and constructions
- Diagnostics of hygrothermal behaviour of constructions and spaces of real buildings
- Optimization of design of building constructions with regard to moisture and microbiological risks
- Computer simulations of transfer of heat and moisture transfer, and risks of mold growth

Hygrothermal Laboratory

Measuring of thermal and moisture characteristics of building materials, constructions, and spaces

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Třinecká 1024,
273 43 Buštěhrad,
Czech Republic
hygrothermal.laboratory@uceeb.cz
+420 224 356 711
+420 778 411 622

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About the Laboratory

The aim of the laboratory is to provide comprehensive measuring of physical parameters related to the transfer and accumulation of heat and moisture in building materials, constructions, and spaces. The equipment allows for laboratory measuring as well as for in-situ measuring (at the construction site).

Measurements and Surveys

Accredited Measurement

- Determination of thermal resistance using a heat flow meter (EN 12667), determination of water vapor transmission properties (EN ISO 12572), determination of moisture content by drying (EN ISO 12570)

Other Measurements

- Determination of hygroscopic sorption properties, capillary absorption, open porosity, and weight by volume

Diagnostics of Constructions

- In-situ measuring and analysis of hygrothermal problems of constructions

Computer simulations

- Simulations of transfer of heat and moisture, optimization of design of building constructions and spaces

Instrumentation

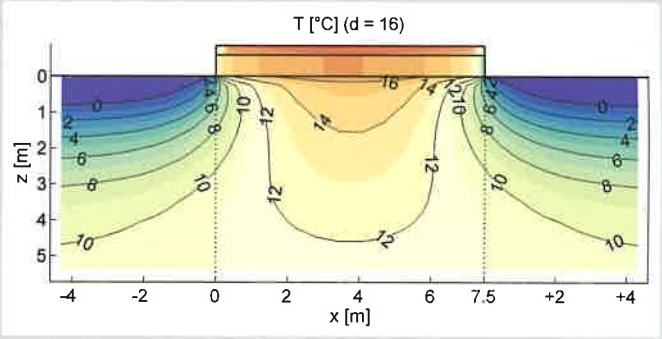
- Small double climate chamber (samples with dimensions up to 1.0 × 1.0 × 0.6 m, thermal range from −45 °C up to +180 °C)
- Devices for measuring of heat conductivity of building materials: heat flow meter (HFM), Isomet
- Device for measuring of water vapour permeability
- Set of cabinet vacuum desiccators
- A&D sensors for measuring of temperature, relative humidity, heat flow, wind speed, solar irradiance, pressure difference, etc.

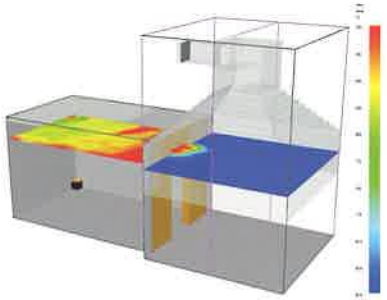
Software Equipment

- Delphin 2D
- Comsol, Matlab

References

- Diagnostics and analysis of hygrothermal and microbiological behaviour of cold deck flat roofs and of composition of cold attics
- Influence of hydrophobization of wood on its sorption properties and water vapour permeability
- Simulation of moisture buffering effect in an interior using clay panels
- Experimental Crawl Space (analysis of hygrothermalbehaviour and microbiological risks in the space under raised floors)
- Air permeability of a roof structure with a sprayed PU foam
- Drying of moist brick walls with a historical painting





Main Activities of the Laboratory

- Large-scale tests with real fire scenarios in interior as well as in exterior conditions
- Determining the reaction to fire class by means of the Room Corner Test; the large-scale fire test with the sample area up to 30 m^2 that replaces a series of ordinary small-scale tests in the cases when it is not possible or suitable to test the product in a small scale
- Calculations of the fire resistance of constructions and mathematical modelling of fire dynamics, of extinguishing and of evacuation
- Development and optimization of structural elements from the fire safety point of view
- Consulting and advisory activity in the field of fire safety engineering

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Třinecká 1024,
273 43 Buštěhrad,
Czech Republic
firelab@uceeb.cz
+420 224 356 711

UCEEB

FireLAB Fire Laboratory

Large-scale interior and exterior fire tests

CTU

UCEEB

About the Laboratory

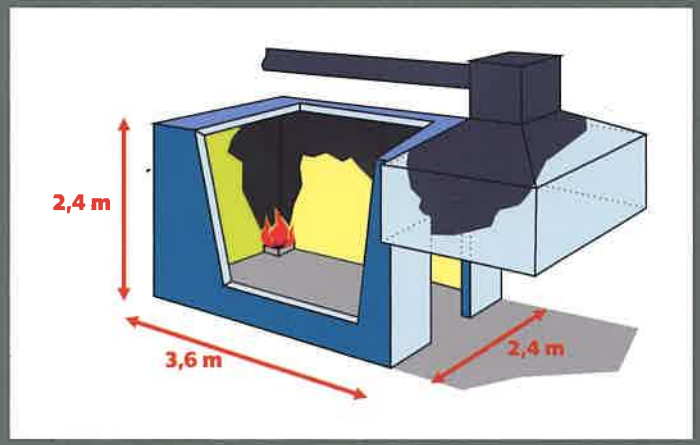
The FireLAB fire laboratory is focused primarily on testing in the real scale (behaviour of surface products, of structural elements or of an object as a whole in case of fire), on testing of extinguishing and cooling with water mist, or on evacuation evaluation.

FireLAB offers a unique testing device: the Room Corner Test to test behaviour of surface products of walls and ceiling or behaviour of objects burning individually. The device is adapted for physical and chemical analysis of combustion gases, including the effects of toxicity.

In the field of fire safety engineering, FireLAB deals with mathematical modelling of fire behaviour of constructions, of fire dynamics, and of evacuation, and it further offers expert fire safety evaluations of constructions.

Tests and Measurements

- Heat release rate and mass loss rate
- Temperature, thermal flow, and flow velocity of gases
- Surface flame spread
- Optical density of smoke and composition of fumes



The testing device consists of:

- Fire chamber (2.4 × 3.6 m / height 2,4 m; testing area of walls / ceiling: 23.0 / 8.6 m^2)
- Hood and exhaust duct with sampling probes
- Adjustable gas burner with the heat output from 1 up to 300 kW
- Thermocouples, radiometers, velocity probes, O_2, CO and CO_2 analysers and instruments for measuring the optical density of smoke as well as the infra-red spectroscopy analysis of combustion gases (FTIR)

References

- Fire safety test of a passenger vehicle at UCEEB (in cooperation with Technical Institute of Fire Protection in Prague); determination and evaluation of effects of fire inside the vehicle and around it (heat release rate, temperature distribution, thermal flow)
- Fire safety test of the curtain wall Envilop Fire; development and optimization of the composition of a specific panel type of curtain wall based on wood and its tests of fire resistance
- Evacuation of the double-deck rail car CityElefant (in cooperation with Testing Laboratory for Railway Vehicles; determination of movement characteristics of persons during the simulation of an emergency exit from the vehicle)

Hlavní aktivity laboratoře

- kvantitativní popis procesů rozhodujících o mikroklimatických podmínkách a zadržení dešťové vody v městských sídlech
- měření fyzikálních a hydraulických vlastností člověkem vytvořených a přirozených půd, které jsou součástí staveb nebo městského prostředí.
- podrobný hydrometeorologický monitoring na třech stabilních stanicích v areálu UCEEB ČVUT v Praze a na jedné mobilní stanici pro operativní nasazení v terénu

Univerzitní centrum energeticky efektivních budov ČVUT v Praze

- Cílem centra je komplexně pomáhat vzniku staveb, které jsou energeticky efektivní, přátelské k životnímu prostředí a svým obyvatelům poskytují patřičný komfort.

Kontakt:
Třinecká 1024,
273 43 Buštěhrad
doc. Ing. Michal Sněhota, Ph.D.
hydrometeo@uceeb.cz
+420 224 356 711

UCEEB

Laboratoř hydrometeorologie a hydropedologie

Systém půda-vegetace-atmosféra v urbanizovaných oblastech

ČVUT

UCEEB

O laboratoři

Laboratoř hydrometeorologie a hydrogeologie se zabývá experimentálním výzkumem a modelováním toků vody a energií v systému půda-vegetace-atmosféra v prostředí lidských sídel. Zaměřuje se na výzkum hydrologie vegetačních střech, staveb pro hospodaření s dešťovou vodou, propustných dlažeb a jiných prvků zelené infrastruktury.

Prováděná měření a hodnocení

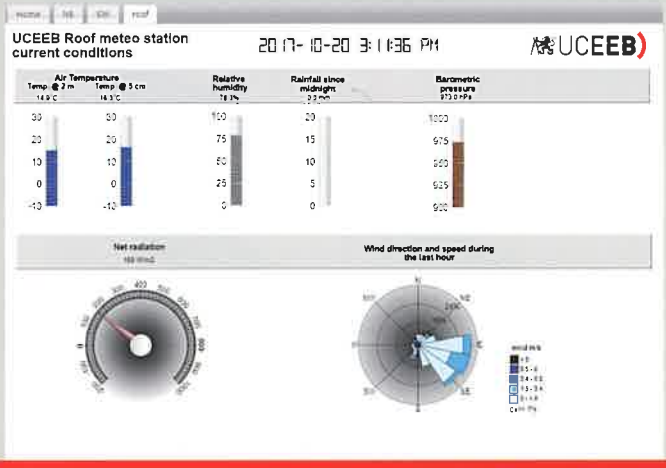
- měření retenčních charakteristik, propustnosti a hydraulické vodivosti porézních materiálů
- měření hydrometeorologických veličin (teplota vzduchu, vlhkost vzduchu, rychlost a směr větru, tlak vzduchu, srážková intenzita/úhrn, solární radiace, půdní vlhkost)
- posouzení strukturálních změn antropogenních půdních systémů v čase

Přístrojové vybavení

- Decagon WP4C (retenční schopnost pórovitých materiálů v oblasti nízkých vlhkostí)
- podtlakový aparát (retenční čára v blízkosti nasycení)
- reflektometr TDR100 (půdní vlhkost)
- meteostanice (2 pozemní, 1 na střeše budovy UCEEB ČVUT v Praze a 1 mobilní)
- zkušební plochy (2 oplocené plochy v areálu a střešní plochy UCEEB ČVUT v Praze)

Reference

- sledování vývoje struktury substrátu vegetační střechy. Posouzení vlivu změny struktury na vlhkostní a teplotní režim souvrství zelené střechy
- měřené řady hydrometeorologických veličin od r. 2014 pro areál UCEEB
- měření vodního režimu antropogenní půdy vytvořené na brownfield v areálu UCEEB
- měření retenční schopnosti substrátů pro souvrství zelených střech
- GAČR GP14-10455P: Vliv strukturálních změn na vlhkostní a teplotní režim antropogenních půdních systémů
- GAČR 17-21011S: Transport vody, nerozpuštěných látek a tepla v člověkem vytvořených půdách městské zelené infrastruktury



Main Activities of the Laboratory

- For architects and developers, we offer analyses, optimization and professional consultations leading to the improvement of construction projects performance
- We offer contractual research in the area of environmental impact of building materials, constructions and buildings
- We provide professional support for contract owners for new buildings and reconstructions of green buildings
- We consult and process energy concepts of cities and villages
- We collaborate on the creation of strategies of smart cities and villages development

SBToolCZ

University Centre for Energy Efficient Buildings CTU in Prague

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Třinecká 1024,
273 43 Buštěhrad,
Czech Republic
Ing. Antonin Lupisek, Ph.D.
sustainability@uceeb.cz
+420 777 215 770

UCEEB

Sustainable Building Laboratory

Design, optimization and certification of green buildings

CTU

UCEEB

About the Laboratory

The laboratory deals with the problems of sustainable construction during the whole life cycle. It offers a new approach to design, construction and operation of buildings and urban districts so that they fulfill a wide range of functional, economical, environmental, social and cultural demands. We guide the investors of new buildings and reconstructions of green buildings through the process of creation of the project specification.

Instrumentation

- Software for life cycle modelling (SimaPro)
- Access to databases of environmental impact of materials and products (Ecoinvent)
- Custom tools for evaluating and certification of the environmental impact of constructions and buildings (SBToolCZ and others)

SimaPro

ecoinvent Centre

Areas of Expertise

- Concept of green buildings and urban complexes
- Environmental impacts of the construction industry
- Complex evaluation of building quality
- Life cycle assessment of constructional elements and buildings
- Assessment of the life cycle of construction elements and buildings
- Support of green public procurement in construction (GPP)
- Corporate social responsibility (CSR) – consultancy in the area of reducing the environmental impact of building stock and technologies
- Consultancy in the area of legislation in energy and environment in the construction industry of the EU
- Trainings and consultancy in the area of green building
- Circulatory economy and recycling in the construction industry

References

- Development and professional guarantee of the SBToolCZ certification system (www.sbtool.cz)
- Study for reducing the environmental impact of the Ministry of Labour and Social Affairs of the Czech Republic based on the principle of life cycle assessment
- Participation in the Airhouse team at the U.S. Solar Decathlon 2013 competition
- Carbon footprint in the construction industry – research of tools and approaches in the EU
- Analysis of the Czech, German and Austrian legislation related to the energy demands of buildings
- Proposal of complex retrofit of a primary school, management of participation groups with users for the town of Buštěhrad
- Proposal of a hybrid autonomous energy system of the Březník object for the Šumava national park
- Professional partnership of the Czech Off-Grid Houses contest
- Creation of the Smart City concept for the Prague 3 municipality

Main Activities of the Laboratory

- Laboratory measurements of airborne sound insulation of building constructions
- Laboratory measurements of impact sound insulation of building constructions
- Laboratory measurements of flanking sound transmission through raised floors and suspended ceilings
- Measurements and calculations of airborne and impact sound insulation in buildings
- Measurements and calculations of room acoustical parameters of buildings

Acoustic Laboratory

Measurements and calculations in the field of building acoustics and room acoustics

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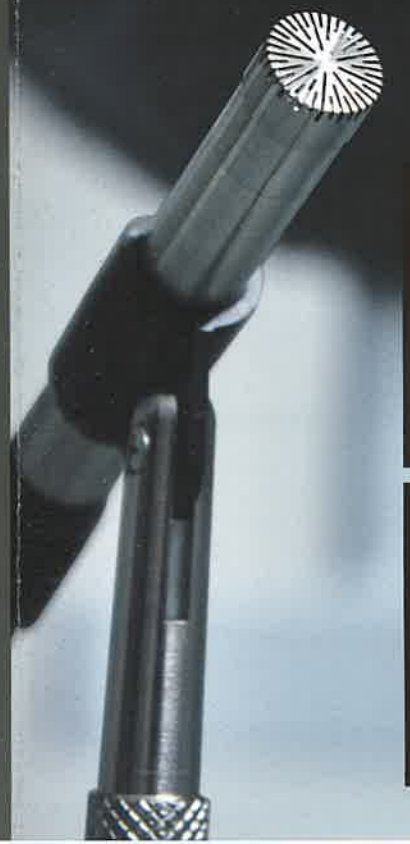
Třinecká 1024,
273 43 Buštěhrad,
Czech Republic
acoustic.laboratory@uceeb.cz
+420 224 356 701
+420 224 356 714

UCEEB



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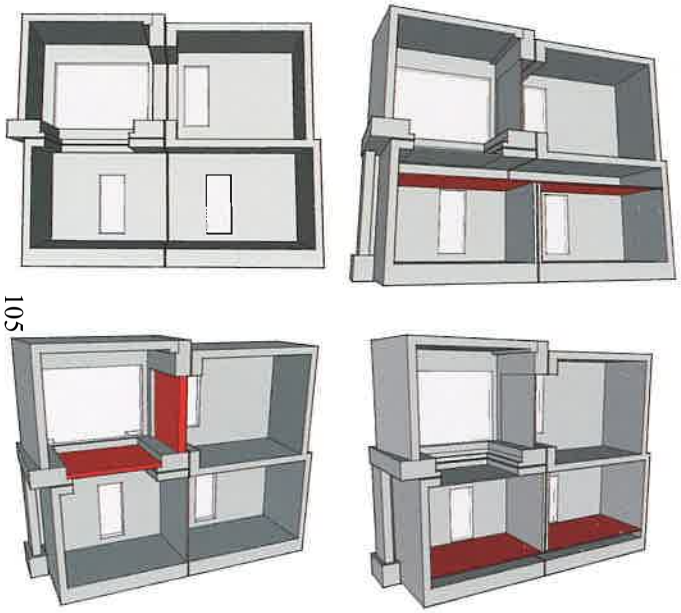
About the Laboratory

The acoustic laboratory of the university centre is focused on building, room and urban acoustics. Besides modern testing instrumentation, it has its own facility in accordance with EN ISO 10140-5 for laboratory measurements of sound insulation of building elements (walls, floors, suspended ceilings and raised floors).



Parameters of Testing Openings

Opening for walls (h x w): **2.4 x 4.2 m**

Opening for floors: **2.9 x 4.4 m**

Ground plan dimensions of lower chambers (integration of raised floors resp. suspended ceilings):

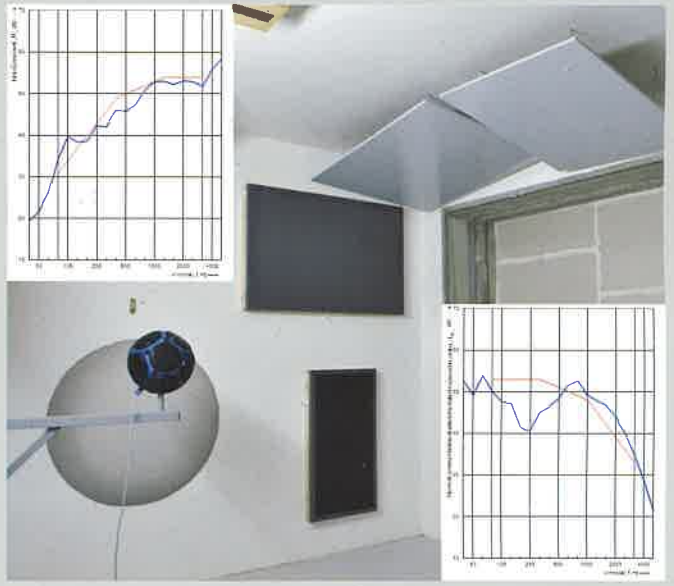
4.5 x 5.0 m and 4.15 x 5.0 m

Instrumentation

- Multi-channel measuring system Nor850, sound analyzers Nor140, acoustic calibrator Nor1251
- Omnidirectional loudspeaker Nor276 with the power amplifier Nor280, source of impact sound Nor277 (tapping machine)
- Dynamic actuator (Gösele system), vibration calibrator Vc20, software for room acoustics
- ODEON v. 13

References

The acoustic laboratory carries out many activities in the field of research, development and cooperation with the commercial sphere. Among others, measurements of airborne sound insulation of the lightweight curtain wall system Envilop that had been developed in the university centre and that can be used as a sustainable replacement for boletic panels took place here. Furthermore, measurements of sound insulation of a new floor panel for subtle prefabricated skeleton from high-strength concrete was carried out here.



The acoustic laboratory performed tests on many other structures as well:

- gypsum-board partition walls
- brick walls
- facade panels based on wood
- acoustic lining of walls etc.

Primary Activities of the Laboratory

- Performance characterization of liquid, air and dual thermal collectors according to EN ISO 9806
- Measurement of optical characteristics for transparent materials (spectral and angular transmittance)
- Development of mathematical models for solar collectors validated by testing
- Mathematical modeling of energy balance for building with solar collectors
- Development of hybrid photovoltaic – thermal (PV – T) collectors including the production of prototypes
- Development of dual air – water thermal collectors including the production of prototypes

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Třinecká 1024,
273 43 Buštěhrad,
Czech Republic
borivoj.sourek@uceeb.cz
+420 224 356 721
+420 603 224 907

UCEEB

Solar Laboratory SOLAB²

Development, analysis and testing solar energy components

CTU

UCEEB

About the Laboratory

The solar laboratory SOLAB^2 is equipped with indoor test stand for solar collectors with artificial sunlight simulator and outdoor test stand with natural sunlight.

Indoor facility provides unique equipment that allows to achieve the irradiance up to 1000 W/m^2 with the homogeneity of ±15 % in the interior environment on the area of 2,24 × 3,91 m.

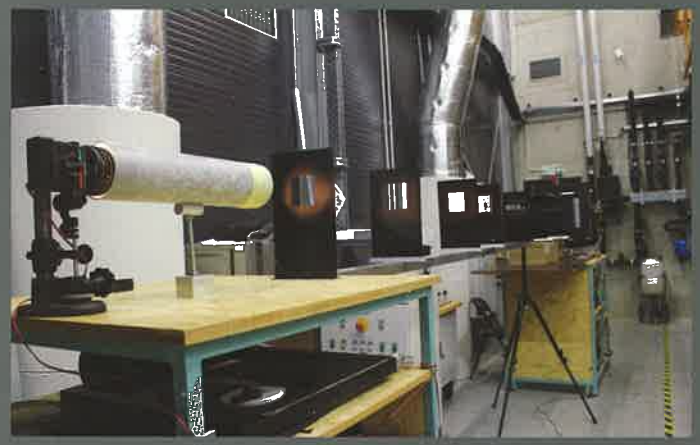
Tests and Measurements (Indoor Test Stand)

Accredited tests of solar thermal collectors in the interior environment according to EN ISO 9806

- Performance tests for liquid and air collectors
- Thermal capacity and time constant
- Stagnation temperature

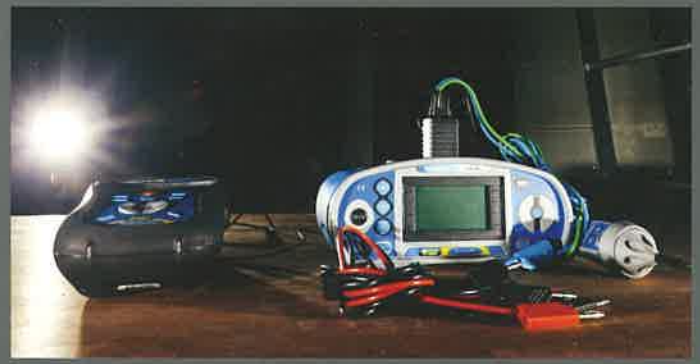
Non-accredited Tests (Outdoor Test Stand)

- Exposure test
- Resistance to high temperatures
- External and Internal thermal shock
- PV characteristics testing for PV-T collectors



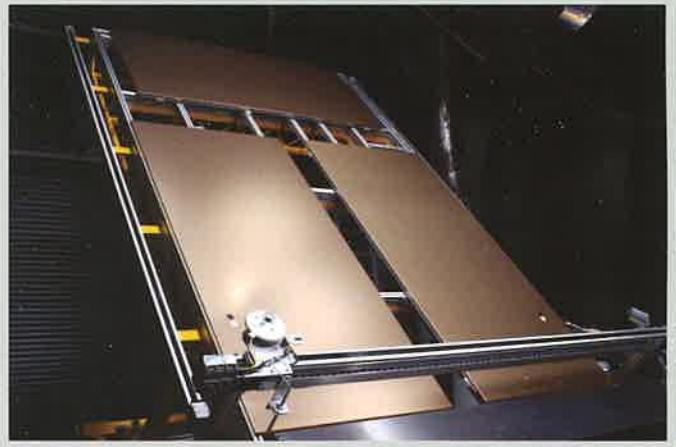
Instrumentation

- Solar simulator with artificial sunlight with indoor test stand
- Outdoor test stand for long-term monitoring of solar components
- Test stand for determining the optical characteristics of transparent materials
- Portable ultrasonic flow & heat meter for pipes DN 10 to DN 2000 for in-situ measurements
- Mertel EurotestPV device for complete testing and diagnostics of photovoltaic panels and entire installations
- Mass flow meters for measuring different kinds of fluids



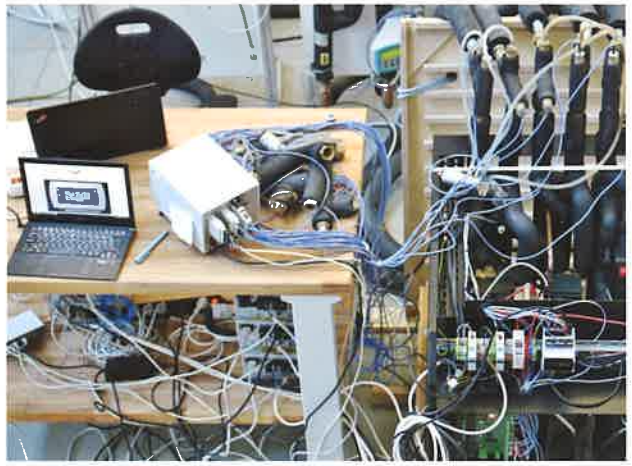
References

- Certification of the REGULUS KPG1 collector in order to acquire the Solar Keymark mark (in cooperation with ITC Zlín, a. s.)
- Test of cohesiveness during an exposition to sunlight for FENESTRA WEIDEN facade components
- Optimization of thermal insulation thickness of a solar thermal collector
- Thermal and electric characteristics of a hybrid PV – T collector integrated into SKANSKA curtain walling facade element
- Measurement of angle dependent transmittance of AGC Raywall45 and Raywall90 optical rasters and their integration into triple glazing



Primary Activities of the Laboratory

- Measurement of electric and thermal performance of heat pumps and cooling devices according to standard procedures
- Tests of non-conventional arrangements of heat pumps and cooling devices
- Research in the area of efficiency improvement of heat pumps and cooling devices (new refrigerants, advanced circuits)
- Detailed mathematical modeling of heat pumps and their integration into thermal systems
- Development of heat pumps as elements of development of decentralized energetics
- In-situ inspection and diagnostics of heat pumps using the ClimaCheck analyzer
- Energetic-economic optimization of heat pumps from the point of view of their year-round operation



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Třinecká 1024,
273 43 Buštěhrad,
Czech Republic
tomas.straka@cvut.cz
+420 224 356 721
+420 724 324 445

UCEEB

Laboratory of Heat Pumps

Research, development and testing of heat pumps and cooling devices

CTU

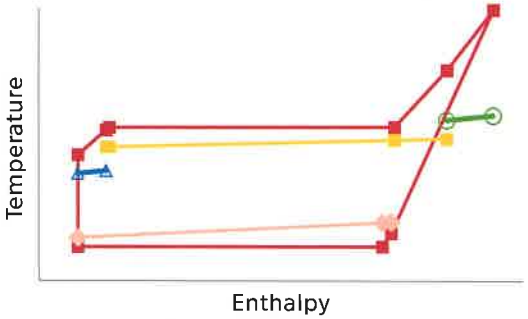
UCEEB

About the Laboratory

The laboratory is equipped with a double box for testing heat pumps with heat capacity ranging from 3 to 50 kW. It allows to test ground-water, water-water and air-water heat pumps as well as to test specific devices with a refrigerant cycle. For inspection of cooling devices in real operation, the ClimaCheck analyzer is available.

Testing and Measurement

- Heat pumps testing according to EN 14511 for determining the characteristics of heat output and coefficient of performance (COP)
- Heat pumps testing according to EN 14825 for determining the seasonal coefficient of performance (SCOP) and its optimization for energy labelling
- Testing of advanced circuits of heat pumps with desuperheater, subcooler, etc.

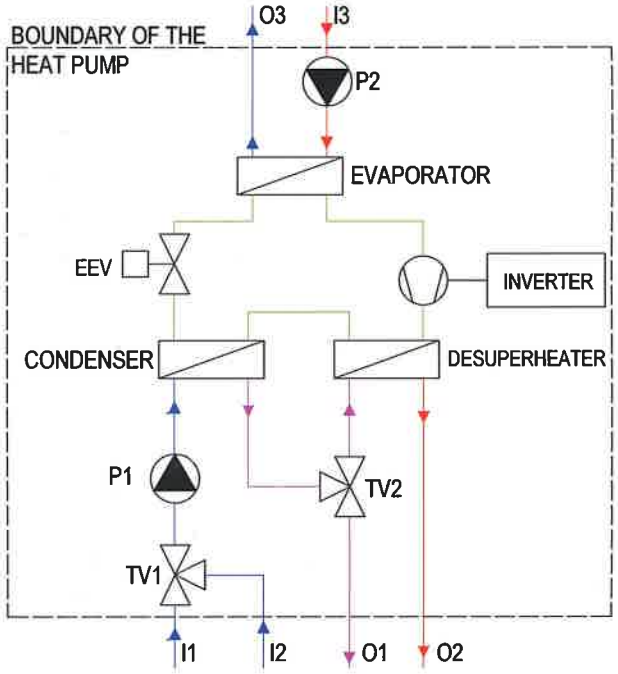


Instrumentation

- Multi-purpose climate chamber (test box) with two separated rooms
- Interior box (3,5 × 3,0 × 2,6 m) with double wall for preserving the extreme climatic conditions: −20 °C / +30 °C
- Exterior box (2,8 × 4,1 × 3,5 m) with the possibility of connecting to the interior box
- Two separate measuring loops for testing ground, water and air source heat pumps with the heat capacity from 3 to 15 kW and from 13 to 50 kW
- Portable analyzer of heat pumps and cooling devices for function and performance diagnostics during operation

References

- In-situ diagnostics of the heat pump in Dubenec school (verification of declared heat capacity after cycle modification)
- Experimental validation of the mathematical model for a multi-exchanger ground source heat pump (REGULUS, within the FP7 project MacSheep)
- Optimization of the air-water heat pump prototype and testing (SCHLIEGER)
- Experimental validation of the mathematical model for a heat pump with variable speed compressor (research project of Technology Agency of Czech Republic)



Primary Activities of the Laboratory

- Design of optical sensor systems (vibration sensors, mechanical strain sensors, temperature sensors and moisture sensors)
- Tests of optical sensors
- Welding and connecting the optical fibers
- Development of electronics for processing and evaluating the measured quantities
- Simulation of optical components using the finite element method
- Renting the laboratory instruments

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Třinecká 1024,
273 43 Buštěhrad,
Czech Republic
fiberoptics@uceeb.cz
+420 224 356 753
+420 224 356 751

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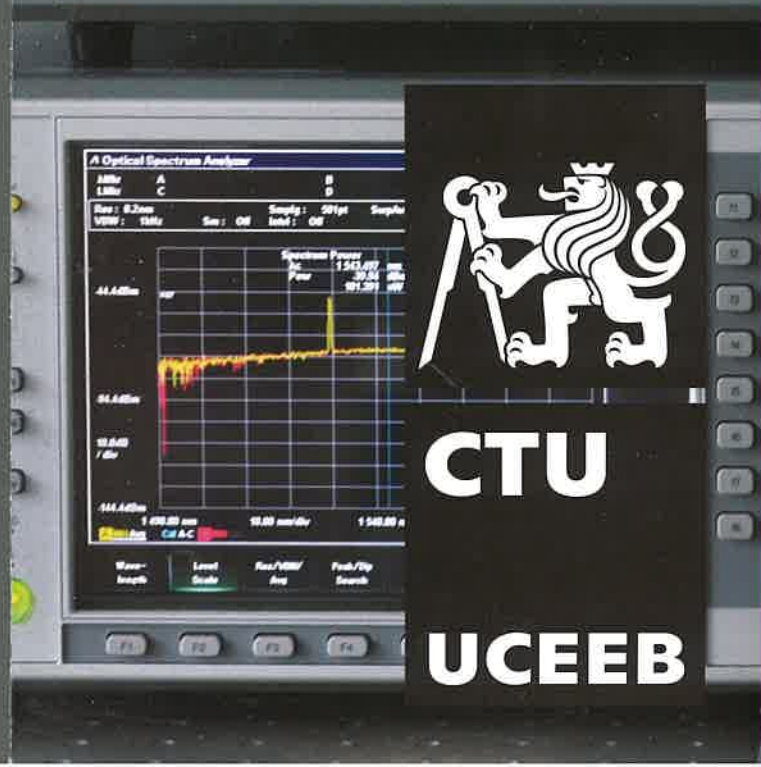
Laboratory of Fiber Optics

Development of fiber optic sensor systems



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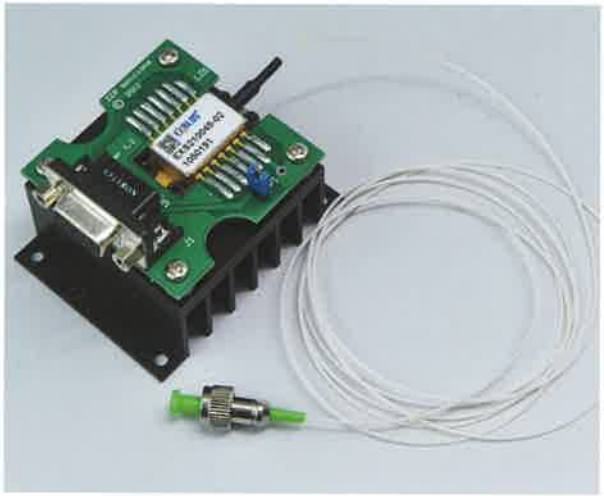
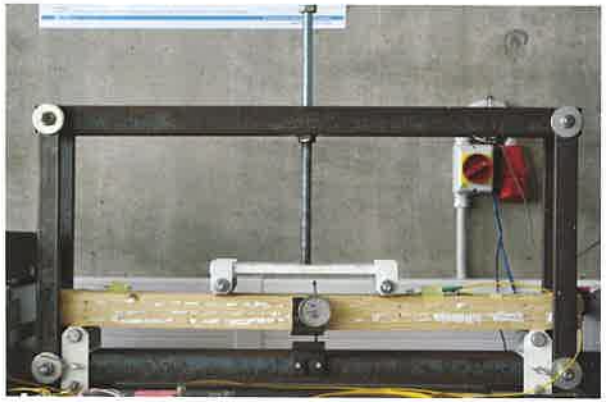
About the Laboratory

The Laboratory of Fiber Optics deals with the design of optical sensor systems from simulation to final production. Thanks to being equipped with the top instruments, the laboratory allows to test the optical systems and to develop the necessary electronics for evaluating the measured quantities.



Carried-Out Tests

Test of straining the sample of glued laminated beam with built in fiber optic sensors.

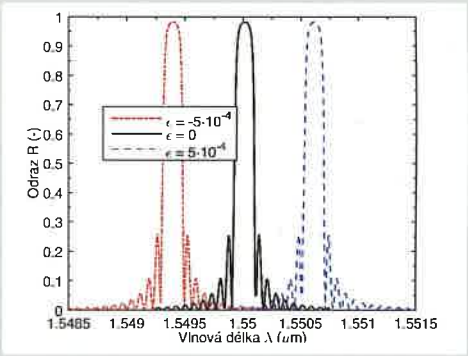


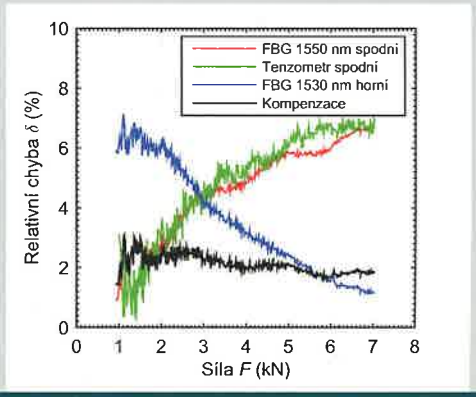
Instrumentation

- Spectral analyzers – measured spectrum from 200 to 1750 nm, precision of measuring ±20 pm, dynamic range up to 60 dB
- Interrogator – measured spectrum from 1270 to 1650 nm, precision of measuring ±1 pm, maximum number of wave channels 1000, detection threshold ¬40 dBm
- Laser source – C+L band, width of the spectral line <100 kHz, tuning step: 1 pm, output 15 dBm
- Welding kit – Fitel S178A including the optical fiber breaker, quick weld in seven seconds, allows for directly welded-on connectors

Example of Laboratory Measuring

- System for monitoring the mechanical straining of wooden structures is currently being developed in the laboratory. Measuring of proportional reshaping of glued laminated beams using Bragg grating which is integrated into the beam as early as during its production is carried out. Electronics and software for processing the measured data are developed in the laboratory. In case of overloading of some of the load-bearing components, an alarm is triggered.
- Besides the development, measuring of light spectrum of the solar simulator was carried out as well. The laboratory allows for measuring the changes of position with the order of hundreds of nanometers and the vibrations using an interferometer.





Main Activities of the Laboratory

The laboratory of composite structures makes possible to develop (among others) the materials and structures including the testing of their mechanical and rheological properties and durability such as:

- ultra-high performance concretes (UHPC), non-reinforced, reinforced using different types of fibers
- construction elements of UHPC using technical textile reinforcement (TRC)
- composite materials using waste materials (recycled construction and demolition waste, foam glass made from recycled glass and others)

Laboratory of Composite Structures

Development of structures and materials based on cement composites

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Třinecká 1024,
273 43 Buštěhrad,
Czech Republic
composite.laboratory@uceeb.cz

UCEEB

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About the Laboratory

The laboratory of composite constructions and materials deals with the development of materials based on cement composites, ranging from ultra-high performance concretes and concretes with special reinforcement to concretes made using recycled materials. Furthermore, the laboratory carries out evaluations of properties of these materials.

Tests and Measurements

The tests of properties of aggregate for concrete and properties of fresh concrete are performed in this laboratory. Furthermore, the mechanical, deformation and rheological properties and durability of hardened concrete are examined there. The room with constant environment for storage of samples belongs to the laboratory.

Instrumentation

- Electromagnetic sifter, pycnometers, drying chamber (tests of aggregates)
- Automated Vicat apparatus, calorimeter, pressure pot (tests of fresh concrete)
- Channels equipped with a datalogger for tests of shrinkage of concrete
- Compression machine for tests of compression strength, flexural strenth and modulus of elasticity in compression (tests of mechanical and deformation properties), testing equipment for freeze-thaw resistance

References

The laboratory of composite constructions carries out many activities in the field of research, development and cooperation with the commercial sphere. Among others, a subtle corpus with detachable covers for the CapaSitty (www.capasitty.com) smart bottle that had been produced here as a prototype, was developed here from the mixture of ultra-high performance concretes. Furthermore, mixtures of light gravel with e.g. foam glass made from recycled glass are developed in the laboratory for usage in thermally-insulating constructions. Dummies of freshwater pearl mussel from high-durability concrete were made here for the T. G. Masaryk Water Research Institute.

Primary Activities of the Laboratory

- Leading the projects associated to proposal, development and testing of a prototype of a unit for combined production of electricity and heat based on the ORC principle for industrial use
- Development and testing of devices for using waste heat from industrial processes
- Development and testing of new types of expanders
- Optimization of components for ORC devices
- Innovation of devices with combined thermal cycles

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Třinecká 1024,
273 43 Buštěhrad,
Czech Republic
lorca@uceeb.cz
+420 224 356 722
+420 737 913 072

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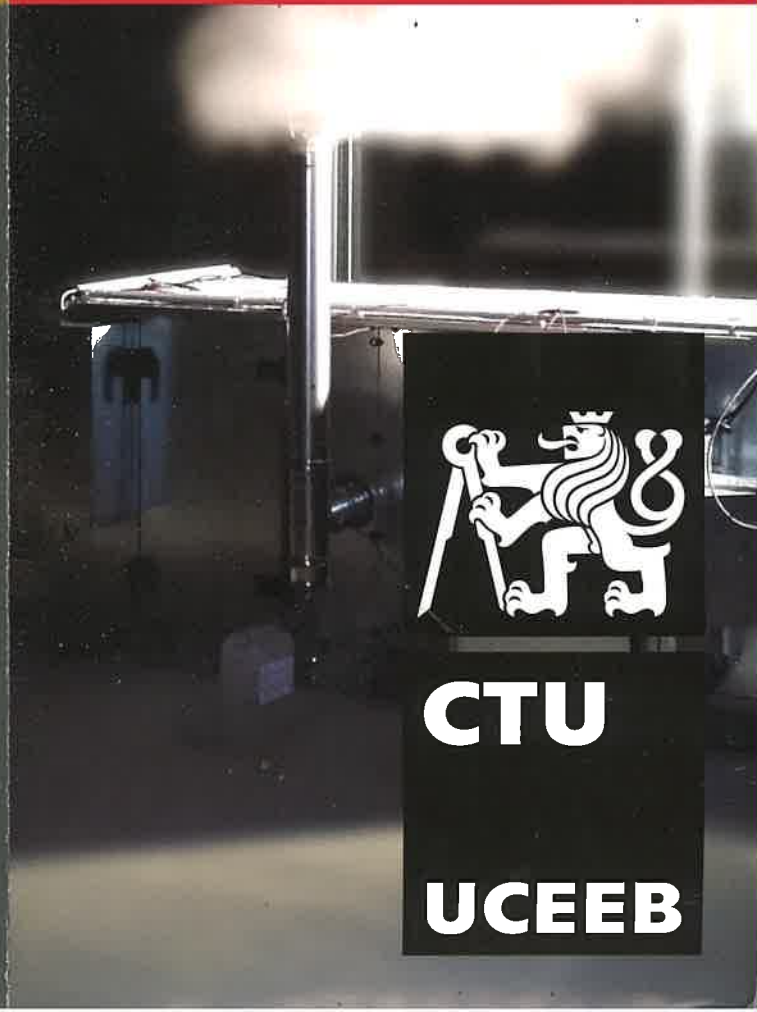
Laboratory of Organic Rankine Cycles and their Applications

Development of technologies in the field of combined production of electricity and heat



CTU

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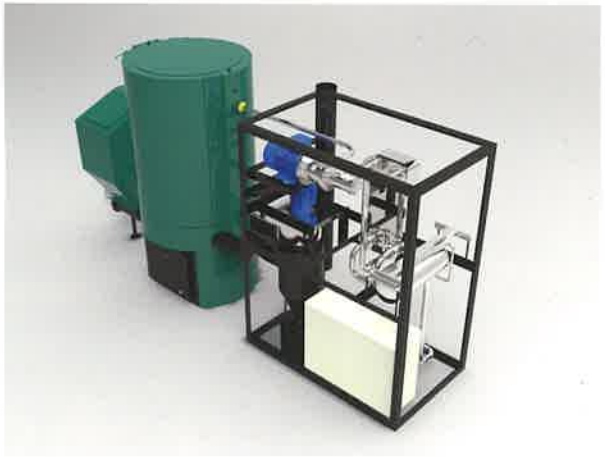
About the Laboratory

The Laboratory of Organic Rankine Cycles and their Applications (LORCA) is focused primarily on the development and testing of prototypes of devices based on the organic Rankine cycle (ORC) principle and their components as well as on the optimization leading to production of competitive solutions on the market. Two directions are followed:
use – recycling of waste heat in industry, and combined production of electricity and heat with low output.



Parameters of Units

Micro power plant WAVE
Heat output: 50 kW
Electric output: 1.5 kW

Simulator of waste heat
Output: 50–150 kW
Temperature: 250–450 °C

Parameters of the MT unit
Use of waste heat
Electric output: 5 kW

Instrumentation

- Simulator of waste heat
- Analyzer of combustion products Testo
- Device for testing the ORC components
- Microturbine Capstone C30

Example of Carried-out Measuring

- Measuring of operational parameters of a heating unit
- Measuring of consumption, operation states, efficiency

Primary Activities of the Laboratory

- Laboratory analysis of the thermal environment and its perception by a person
- Laboratory analysis of fluid flow using the method of laser anemometry
- Complete analysis of internal environment in real operations (thermal well-being, air quality, lighting, acoustics, electro-ionic environment) by measuring using a mobile set and carrying out an evaluation
- Subjective perception of the environment by users
- Optimization of operational parameters of systems for securing the environment
- Development and testing of new devices for heating, cooling and ventilation in rooms
- Energetic optimization of systems of technical devices of buildings for achieving as high a quality of the environment as possible while keeping the energy consumption at minimum

University Centre for Energy Efficient Buildings CTU in Prague

- The aim of the Centre is to promote energy efficient and environmentally friendly buildings that are comfortable for their users.

Třinecká 1024,
273 43 Buštěhrad,
Czech Republic
dual.climaticcabin@uceeb.cz
+420 224 357 104
+420 778 403 299

UCEEB)

Laboratory of Indoor Environment – Dual Climatic Cabin

Quality of the indoor environment for a person

CTU

UCEEB

About the Laboratory

The laboratory is focused on the development in the field of internal environment, especially on thermal well-being and on the air quality in buildings. Experiments are carried out in the dual climatic cabin. These are used for analyzing the environment with various devices for heating, cooling and ventilation. The aim is to improve the characteristics of these devices in order to increase the quality of the environment as well as to improve the use of energy.

Parameters

The dual climatic cabin has the form of two identical rooms next to each other, each having the dimensions of 4.4 x 3.1 m and the height of 2.85 m. It is situated in a controlled outer environment with the temperatures ranging from −15 °C to +35 °C. The dual cabin allows to watch the behavior of two different devices at identical borderline conditions or to test two identical devices at different borderline conditions at the same time.

Instrumentation

- Thermal mannequin – a model of human body simulating its response to the surrounding thermal environment
- Laser anemometry – a system for analyzing the air flow in the room based on the capturing of the movement of particles carried by the air
- Analyzers of air quality – a set of devices for measuring the concentration of common gaseous noxious agents and dust and for taking samples

Example of Carried-out Measuring

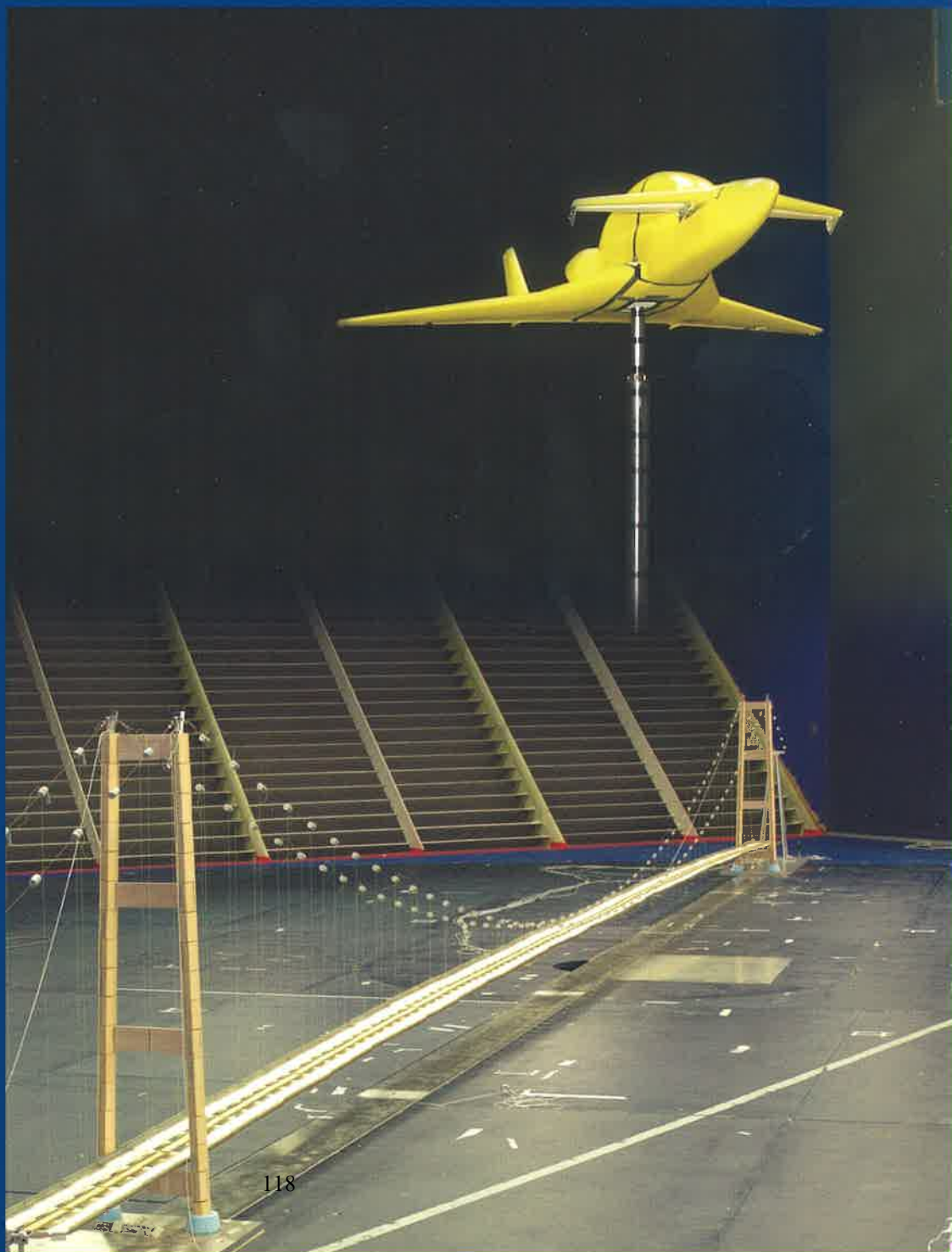
An analysis of the thermal environment with electric heating with six variants of heating systems (e.g. large-area heating, panels, convector) and two ways of regulating them has been carried out in the dual cabin. The aim was to describe the final state of the thermal environment in the zone of staying using the method of standard measuring of thermal fields, using the analysis of flow by means of laser anemometry, and using the thermal mannequin for analyzing the non-uniform perception of the thermal field by a person. Significant differences of distribution of temperature and air velocity in the space were identified and described for different types of heating systems as well as changes in time with different ways of regulating, and energetic indicators of the efficiency of heat sharing by each system were specified.

The laboratory allows to verify the effect of local large-area heating and cooling surfaces (cooling ceilings, heating units, convectors) as well as elements of air-handling systems (cooling girders, ventilator units, personalized ventilation and so on) on the internal environment.

Politecnico di Milano
Galleria del Vento - CIRIVE

Galleria del Vento a Strato Limite e Aeronautica
Boundary Layer and Aeronautical Wind Tunnel

POLITECNICO DI MILANO



Galleria del Vento - Politecnico di Milano

The Politecnico di Milano Wind Tunnel

In alto: la Galleria del Vento del Politecnico di Milano nella sede Campus Bovisa Sud.

Above: Politecnico di Milano Wind Tunnel in Bovisa Sud Campus.

In basso: il render dell'impianto.

Below: the render of the facility.

La Galleria del Vento del Politecnico di Milano (GVPM) si distingue per una duplice vocazione: essere strumento per la ricerca e nello stesso tempo strumento per applicazioni industriali di elevato contenuto scientifico e tecnologico. È un impianto aderente ai più moderni standard tecnologici, per un'efficiente gestione di stile industriale, fortemente radicato nella struttura universitaria del Politecnico di Milano, che si avvale quindi di un know-how scientifico di larghissimo spettro.

Un altro elemento distintivo della Galleria del Vento del Politecnico di Milano è la singolare configurazione a circuito chiuso a layout verticale con presenza di due sezioni di prova, di caratteristiche complementari, ottimizzate l'una per prove di "Ingegneria del Vento", l'altra per prove di ambito "Aeronautico".

L'impianto, unico nel suo genere per versatilità nel panorama mondiale, garantisce l'offerta di un vasto ventaglio di applicazioni. La Galleria è equipaggiata con 14 ventilatori posizionati in parallelo per un totale di 1.4 MW di potenza.

Un sistema computerizzato di supervisione garantisce l'esecuzione di prove con elevato grado di automazione, in conformità ai più recenti standard di sicurezza e qualità di ambito industriale.

As is well known, the Politecnico di Milano Wind Tunnel (GVPM) has a dual aim, being designed to provide the highest technological standards for a wide range of applications. In addition, its location in the academic environment of the Politecnico di Milano denotes a strong commitment to the scientific approach. Thus the GVPM represents two things, being both a purely research tool and, secondly, a modern instrument for high-technology industrial applications offering advantageous reciprocal synergies. Another characteristic of the GVPM is the special closed-circuit configuration, arranged in a vertical layout with two test rooms in the loop. The bigger one is located in the upper part of the loop and is intended for civil engineering testing (i.e., the Boundary Layer Test Section). The smaller one is located in the lower part of the loop and is suitable for aeronautical tests (the Aeronautical Test Section). Due to this unique feature, the GVPM offers the widest possible range of test arrangements and alternatives. The singular facility layout, achieved with the state-of-the art technologies, includes a flow generator array of 14 fans, working in parallel with a total power of 1.4 MW. A computerised control system makes it possible to perform highly accurate test schedules according to well developed new quality and safety standards.

Applicazioni di ingegneria del vento

Wind Engineering

La sezione di prova maggiore consente la generazione dello strato limite turbolento in simulazione di quello associato al vento terrestre. Tale sezione è quindi specificamente dedicata a sperimentazioni nel settore dell'ingegneria del vento.

The wider test section allows the generation of a turbulent boundary layer in order to simulate natural wind. This section is specifically suitable for a wide range of wind engineering applications.

Lo studio dell'interazione vento-struttura è una delle principali aree di ricerca sviluppate presso la Galleria del Vento del Politecnico di Milano. Le grandi dimensioni della sezione di prova (14x4m), unitamente alle possibilità di regolazione del flusso, consentono di simulare lo strato limite terrestre in un vasto campo di rapporti di scala geometrica.

L'impianto è ottimizzato per prove su modelli aeroelastici di ponti a grande luce (fattori di scala 1:100 - 1:300) e su modelli sezionali di impalcato (fattori di scala 1:30 - 1:60), per i quali sono disponibili specifiche attrezzature di prova. La presenza di un tavolo girevole (13m di diametro) in corrispondenza della sezione di prova consente la riproduzione con elevato dettaglio di aree urbane per prove su edifici (fattori di scala 1:50 - 1:100).

Per tali tipologie di prove sono in dotazione sistemi di misura per l'acquisizione di distribuzioni di pressione non stazionarie (più di 200 porte) e sonde ad alta risposta in frequenza per misure di flusso, oltre alla tradizionale strumentazione di galleria.

L'impianto è attrezzato per prove su modelli di imbarcazione a vela tipo Coppa America in scala 1:10 con generazione di "twisted flow" e con "hardware in the loop" per il controllo dello sbandamento dell'imbarcazione. L'impianto presenta caratteristiche adeguate per la realizzazione di test su treni ad alta velocità in scala 1:10 - 1:20 in relazione all'azione del vento laterale e agli effetti dinamici associati alla turbolenza. Le notevoli dimensioni della camera consentono, infine, di affrontare le problematiche connesse alla diffusione di inquinanti su vaste aree.

Wind-structure interaction is one of the main topics researched for the Politecnico di Milano Wind Tunnel (GVPM). The huge dimensions of the boundary layer test section of the GVPM together with the possibility of flow regulation, permit the generation and growth of a turbulent wind velocity profile to match the earth boundary layer on a large scale.

The GVPM is well suited for performing tests on aeroelastic models of long-span suspension bridges (scales: 1/100 to 1/300). Deck section model tests (1/30 to 1/60) are also performed using dedicated tools. A large turntable (13 m in diameter) enables complete models (on a scale of 1/50 to 1/100) of buildings with an amply detailed surrounding to rotate in order to vary the wind incidence angle.

The instrumentation available and the complete measuring and acquisition systems are the standard state-of-the art items, plus a high speed unsteady pressure measuring system (more than 200 pressure taps) and a high-frequency flow measuring system.

The GVPM is highly suitable for testing sailing boats (in the America's Cup class). Due to the considerable dimensions of the test section, it is possible to test large models (on a scale of 1/10 and to operate Twisted Flow generators and "hardware in the loop" devices to control the rolling angle of the boat. Vehicle model testing is also performed in the GVPM. Trucks and trains (1/10 to 1/20 scale models) are tested to investigate lateral wind effects and turbulence-related dynamic effects. The large dimensions of the boundary layer test room (35 m x 14 m x 4 m) are fully exploited for test models of extensive urban areas in order to investigate pollution spread problems.

Grazie alle grandi dimensioni della camera di prova a strato limite è possibile condurre una vasta varietà di studi: l'effetto del vento su edifici, ponti, veicoli, imbarcazioni a vela e cavi tesati.

The large dimensions of the boundary layer test section allow for a wide range of different applications: such as wind effects on buildings, bridges, vehicles, sailing-boats, and taut cables.

Applicazioni aeronautiche
Aereonautical Testing

Le notevoli dimensioni della camera di prova consentono di provare modelli in grande scala e componenti in scala 1:1.

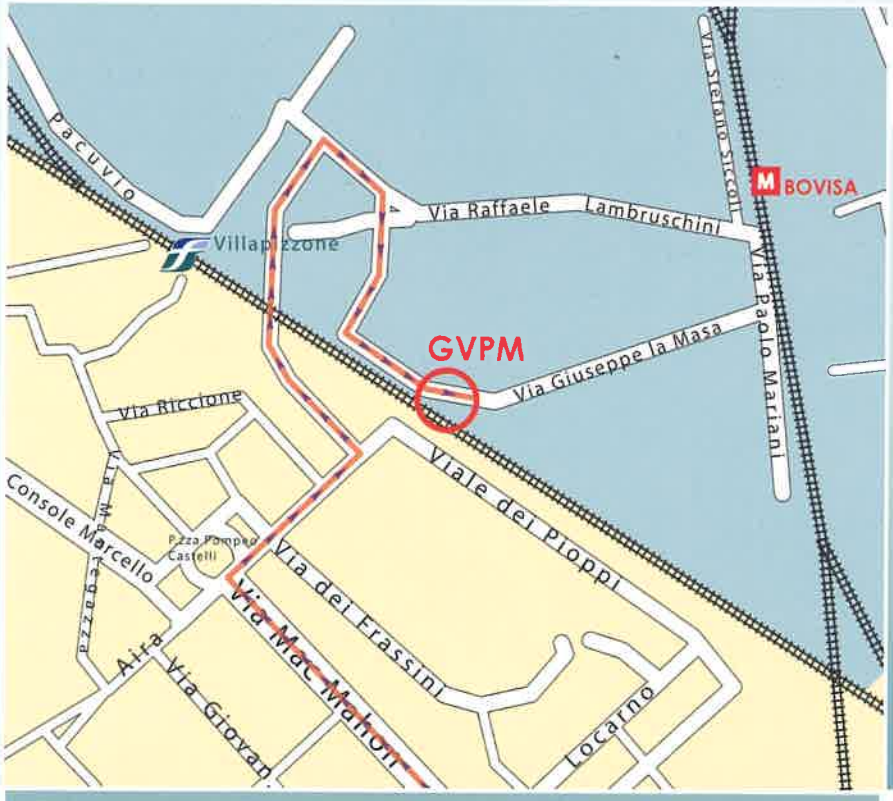
The large size of the test section provides room for extra large models and real-scale components can be tested.

Per ogni aeromobile di nuova concezione o soggetto ad una importante modifica, le prove in Galleria del Vento costituiscono una indispensabile verifica delle prestazioni aerodinamiche. La galleria, inoltre, permette di eseguire prove aeroelastiche per lo studio del comportamento dinamico dei velivoli mediante appositi modelli con rigidezze e distribuzioni di massa opportunamente scalate rispetto al vero. La Galleria del Vento del Politecnico di Milano si inserisce nella categoria degli impianti per prove in regime di bassi numeri di Mach. L'impianto si presta quindi particolarmente bene allo studio delle prestazioni di velivoli di aeronautica generale o di elicotteri, ma presenta notevoli potenzialità anche nello studio di velivoli veloci relativamente alla loro operatività a basso Mach, tipicamente in decollo e in atterraggio. In tutti questi casi, le notevoli dimensioni della camera di prova permettono di realizzare modelli di grandi dimensioni, ottenendo così numeri di Reynolds elevati. Oltre alle prove su modelli di aeromobili completi, possono essere svolti test su singole componenti (prese d'aria motore, piani di coda, etc...).

Any newly-designed (or modified) aircraft needs to be tested in the wind tunnel in order to check its aerodynamic performance.
In addition, the aeroelastic dynamics of the aircraft can be studied in the wind tunnel.
The GVPM *is a low-Mach number wind tunnel suitable for the testing of the general aviation planes and helicopters.*
Furthermore, the GVPM *can reproduce low-Mach number flight conditions (namely take-off and landing) of several high-cruising speed aircraft.*
The capacious test chamber allows for rather large models and therefore quite a high Reynolds number can be accommodated. In many cases, a full scale aircraft component can be directly tested in the wind tunnel (e.g. air intakes, tailplanes, etc).

Nella sezione di prova aeronautica è possibile operare sia in camera chiusa che in camera aperta. La flessibilità dell'impianto rende possibile un'ampia gamma di applicazioni.

The aeronautical test section can operate in both closed and open configuration. The flexibility of the facility permits a wide range of applications.



DOVE SIAMO
how to reach us

La Galleria del Vento del Politecnico di Milano si trova all' interno del Campus di Ingegneria Bovisa Sud, in via Giuseppe La Masa 34, facilmente raggiungibile con mezzi pubblici tramite le Ferrovie Nord Milano (stazione Bovisa Politecnico) o mediante le Ferrovie dello Stato (stazione Villapizzone).
Con mezzi propri il percorso più agevole è il seguente: Autostrada A4, uscita Milano Certosa, Viale Monte Ceneri, Via Mac Mahon, Piazzale P. Castelli (vedi mappa).

Politecnico di Milano Wind Tunnel is located in Bovisa Sud Engineering Campus, Giuseppe La Masa Street n. 34, easily reachable with public transport by Ferrovie Nord Milano (Bovisa Politecnico Station) or by Ferrovie dello Stato (Villapizzone Station).
Our location is also easy to reach driving from A4 motorway, Certosa exit, Monteceneri Street, Mac Mahon Street, P.Castelli Square (see the map).

Una apposita attrezzatura permette di misurare le forze ed i momenti aerodinamici su diverse tipologie di oggetti (con o senza atleta), anche a diversi angoli di derapata. Su questa base possono essere montate diverse attrezzature atte a rappresentare le condizioni specifiche dello sport in esame.
Per le prove di ciclisti, si utilizza un apposito supporto che permette la rotazione di entrambe le ruote e, offrendo un'adeguata resistenza alla pedalata, permette all'atleta di assumere la stessa posizione che assumerebbe in gara.
Per gli slittini o i bob, è possibile montare delle apposite pareti che riproducono la geometria di un rettilineo di pista. Un apposito apparato permette di realizzare interessanti visualizzazioni con fumo, che possono essere riprese dalle telecamere.

A special testing equipment allows to measure aerodynamic forces and moments on various kind of sport equipments (both with and without the athlete) changing also the Yaw angle if necessary. This platform can accommodate various test equipments fitted to correctly simulate the particular boundary conditions of the sport to be tested.
A special bike support allows the athlete to simulate the correct thrust on pedals by the means of an adjustable resistance to the back wheel rotation. Both the wheels are rotating. To test luge and bobsleigh the track geometry is reproduced using movable panels simulating track borders. There is a smoke generator with dedicated lamps that allows to obtain flow visualizations and some cameras to record images.

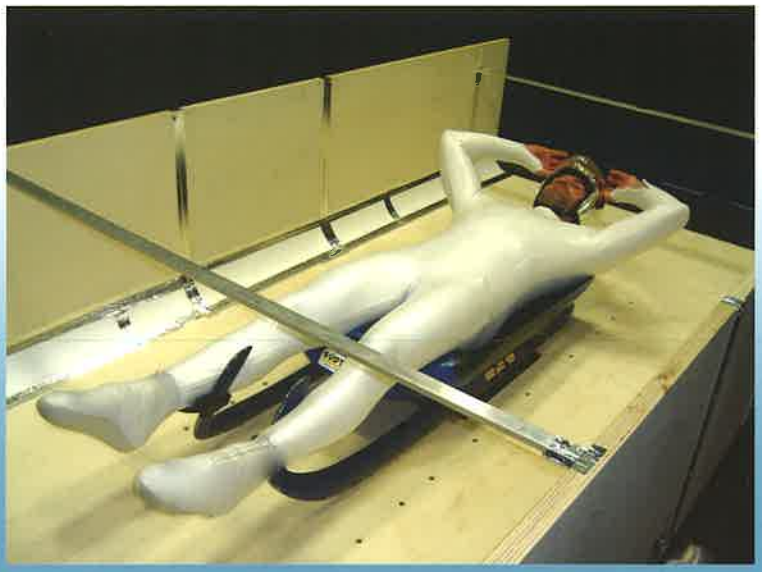


Figura in alto:
lo slittinista Armin Zoeggler in prova sulla apposita attrezzatura che riproduce il profilo della pista olimpica.
Figura in basso:
visualizzazione con fumo sul casco del ciclista Michael Rogers.

Figure above:
the luger Armin Zoeggler testing on the special test rig with the olimpic track profile.
Figure below:
smoke flow visualization on the Michael Rogers's helmet.

Contatti: POLITECNICO DI MILANO - DIPARTIMENTO DI INGEGNERIA AEROSPAZIALE
prof. Giuseppe Gibertini, +39-02-2399-8389, gibertini@aero.polimi.it

Sport
Sport

Le dimensioni della Galleria del Vento del Politecnico di Milano si prestano ad ospitare prove di atleti con le relative attrezzature per svariati tipi di sport.
All'interno della camera di prova, gli atleti sono soggetti alle stesse azioni aerodinamiche che sperimentano in gara e possono, quindi, valutare gli effetti aerodinamici delle diverse attrezzature e delle diverse posture, giungendo ad ottimizzare la propria efficienza aerodinamica.

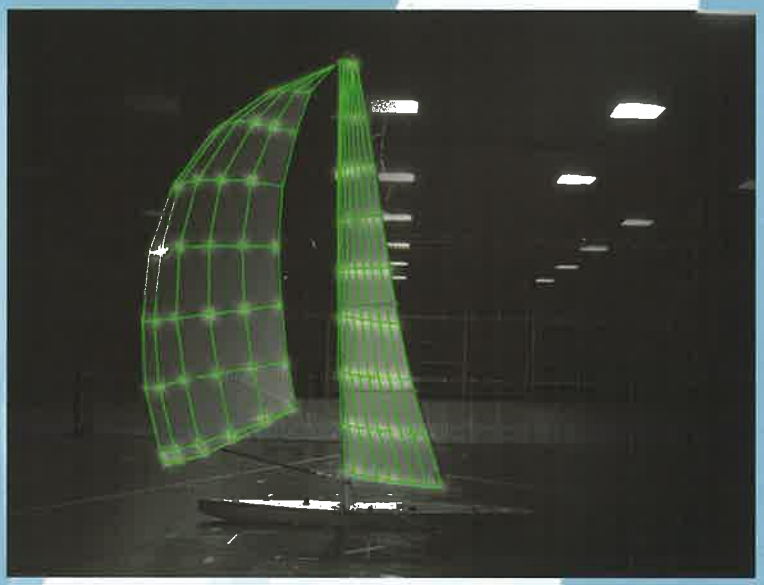
The wind tunnel test section dimensions allows to test athletes of various disciplines with their race equipments.
The athletes inside the wind tunnel are subjected to the same aerodynamics loads as in the races. Thus they can look for the best equipment and position in order to optimize their aerodynamics efficiency.

Figura in alto:
il ciclista Magnus Backstedt in prova sulla apposita attrezzatura che permette di mettere in rotazione entrambe le ruote.

Figure above:
the biker Magnus Backstedt on the special test rig with both turning wheels.

Nella camera di prova a strato limite (14x4m) è stato installato un dispositivo, grazie al quale è possibile generare un'ampia gamma di profili verticali di velocità del flusso sia in termini di modulo che di angolo di attacco (in primo piano nella immagine di copertina). L'ampiezza della sezione consente di utilizzare modelli di imbarcazione di grandi dimensioni (scala 1:10) e di provare anche più imbarcazioni contemporaneamente. Una bilancia dinamometrica misura le 6 componenti di forza e, in parallelo, un sistema di telecamere ricostruisce la geometria 3D delle vele in un ambiente virtuale utilizzabile per la realizzazione di analisi CFD.
Le analisi CFD vengono validate con il dato sperimentale e permettono di conoscere il comportamento locale del fluido in tutta la regione vicino al modello.
La camera di prova ad alta velocità è utilizzata per la realizzazione di test su appendici di carena ad alti numeri di Reynolds.

In the boundary layer test section (14x4m), the onset flow can be made to match the desired vertical wind profile in terms of both absolute value and direction, using a devoted twisted flow device (foreground, figure on cover). The wide dimensions of this test section make it possible to test large-scale models (scale of 1:10) or two models at the same time, to investigate blanketing effects for tactical purposes. A six-component dynamometer balance measures the aerodynamic forces, and a sail detection system simultaneously produces a 3D geometry of the trimmed sail's shape that can be used for CFD analysis. CFD analysis is validate with the experimental result and than allow to investigate the local flow behaviour all over around the yacht model. In the high-speed section, yacht appendages with a high Reynolds number can be tested.



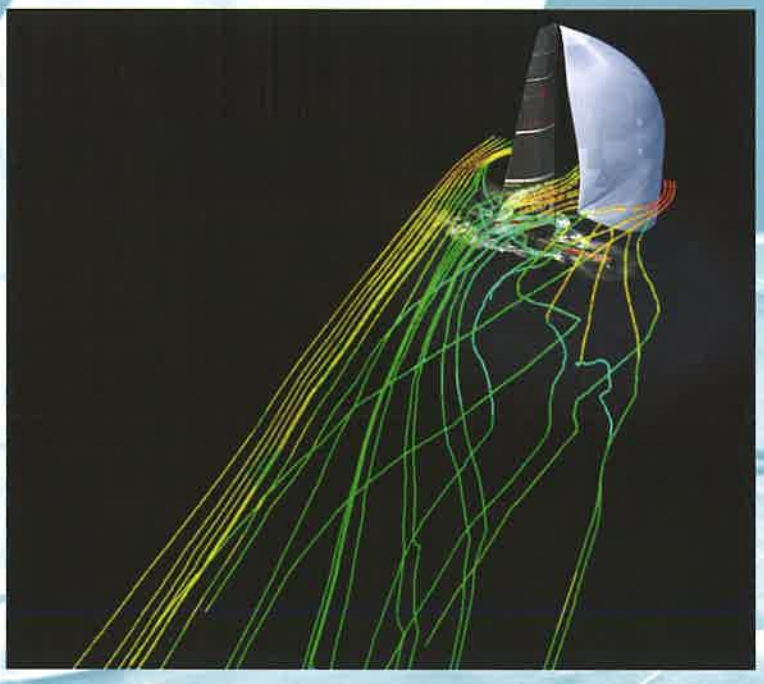
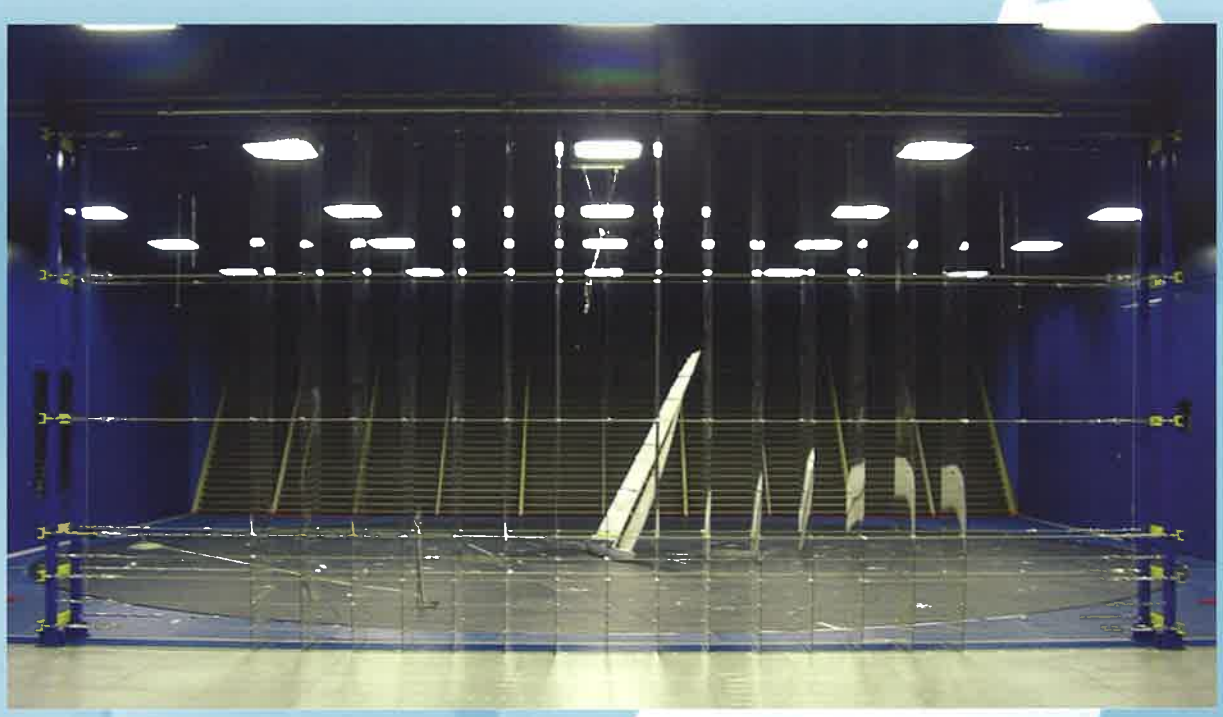


Figura in alto: fotomontaggio dell'imbarcazione vera e del modello 1:12 durante un test in camera a strato limite.
Figura al centro: fotogrammetria per il rilievo delle forme delle vele testate.
Figura in basso: analisi CFD delle forme rilevate e visualizzazione delle traiettorie del flusso.

Figure above: photomontage of the real scale yacht and the 1:12 scaled yacht model during a yacht test in the boundary layer test section.
Figure in the middle: fotogrammetry analysis of the tested sail shapes.
Figure below: CFD analysis of the reconstructed sail shapes and flow trajectories visualization.

Contatti: POLITECNICO DI MILANO - DIPARTIMENTO DI MECCANICA
prof. Giorgio Diana, +39-02-2399 8423, giorgio.diana@polimi.it

Imbarcazioni a vela
Sailing Yachts



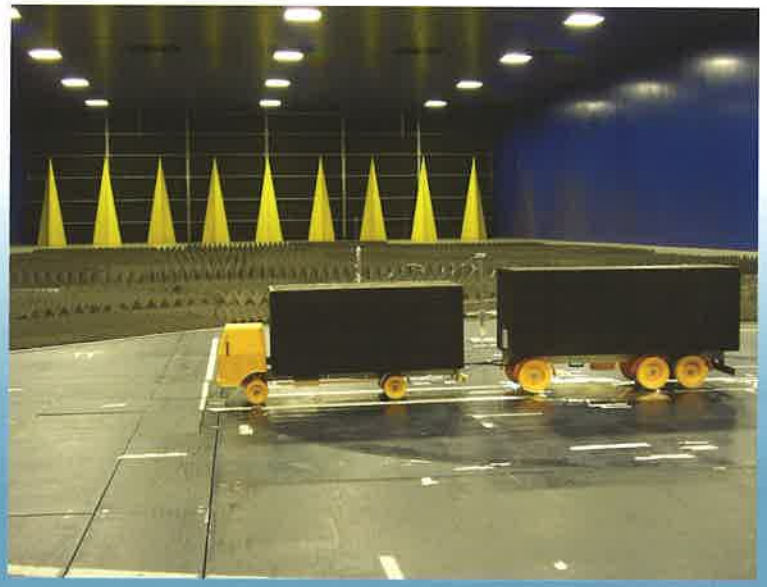
Le prove in Galleria del Vento sono diventate negli ultimi anni uno strumento di progetto fondamentale per le tipologie di imbarcazioni impegnate in regate di alto livello, dalla Coppa America, alla Volvo Ocean Race, fino alle derive delle classi olimpiche. Le tipologie di prova realizzate sono volte alla ottimizzazione di piani velici, alla definizione dei tagli delle vele, alla regolazione dell'albero e alla ottimizzazione delle forme delle appendici di carena. La Galleria del Vento del Politecnico di Milano è riconosciuta come centro di eccellenza mondiale nella dinamica delle imbarcazioni a vela e nell'aerodinamica in generale. L'alta qualità del flusso e le rilevanti dimensioni della camera a strato limite rendono questa Galleria la più apprezzata per test su imbarcazioni a vela.

In the last few years, Wind Tunnel tests have become an essential design tool for improving performance of sailing yachts taking part in top-level competitions, such as the America's Cup, Volvo Ocean Race, and all the Olympic classes. Tests are useful for sail plan, sail design, rig tuning, keel and rudder shape optimization. The Politecnico di Milano Wind Tunnel facility excellence in this field as well in general aerodynamics is world-wide recognised. The very high standards of flow quality of the two test sections, the relevant height and the very large total area of the boundary layer test section, makes of it the most suitable wind tunnel for sailing yacht applications.

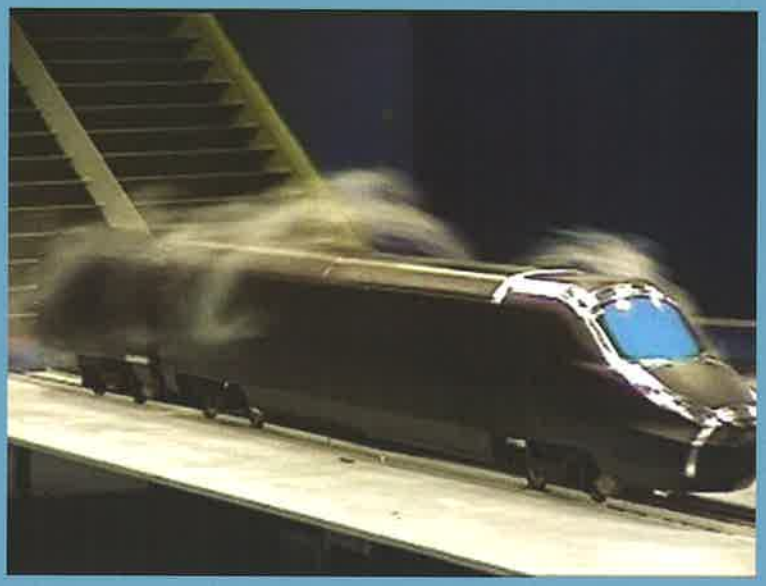
Figura in alto:
modello di imbarcazione durante un test in andatura di bolina in camera a sviluppo di strato limite.
Figure in basso:
analisi CFD di modello di imbarcazione in andatura di lasco e corrispondente prova sperimentale nella camera a stato limite, vista della camera di controllo durante il test, fotomontaggio di una deriva con bulbo in camera a alta velocità.

Figure above:
America's Cup Class Yacht (scaled 1:12) during a upwind test in the boundary layer test section.
Figure below:
CFD analysis of a yacht sailing downwind and the corresponding test in the boundary layer test section, a picture of the control room and a photomontage of a keel and bulb in the high speed section.

La dinamica del flusso attorno al veicolo è studiata sia con tecniche di visualizzazione di flusso (vedi figura centrale) sia mediante misure di pressione sulla superficie esterna del modello. A queste indagini sperimentali, sono affiancati studi numerici con codici di calcolo fluidodinamici (CFD) che permettono di interpretare fisicamente i risultati sperimentali ottenuti e di realizzare analisi di sensibilità al variare di parametri aerodinamici ritenuti significativi (vedi figura in basso).
Infine, partendo dai risultati ottenuti con l'estesa campagna di prove sperimentali realizzate in Galleria del Vento sui modelli in scala, è stata messa a punto una metodologia numerico-sperimentale per la stima del rischio di ribaltamento di veicoli (ferroviari e stradali) investiti da vento laterale.



The fluid dynamics around the vehicle can be analysed through both flow visualisation devices (smoke generators - see middle figure) and pressure taps on the vehicle model surface. For a better understanding of the physical phenomena experimentally observed, wind tunnel tests are integrated with computational fluid-dynamic (CFD) calculations - see bottom figure. These numerical codes also allow to perform sensitivity analysis of the parameters characterising the aerodynamic field. Moreover, a numerical-experimental procedure has been set up, based on the huge database collected over the years during wind tunnel tests, enabling to asses the road/rail vehicle dynamics when exposed to cross winds and to evaluate the rollover risk.



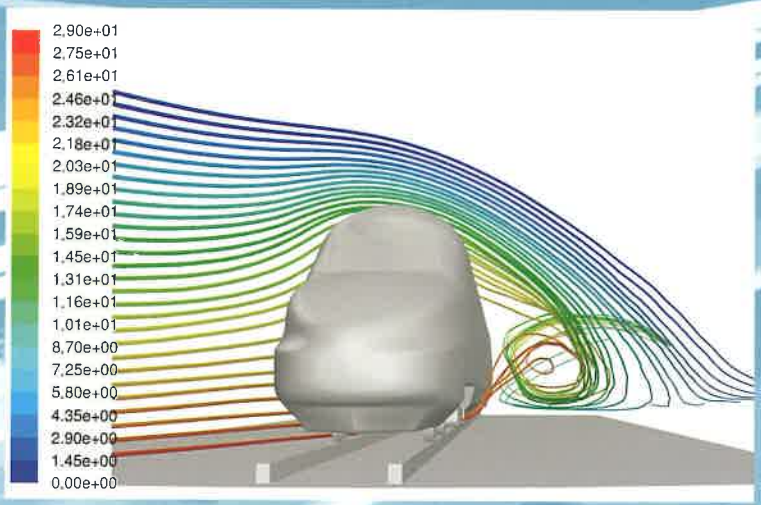


Figura in alto: progetto WEATHER: carichi aerodinamici su VAN + rimorchio. Prove con simulazione del vento turbolento.
Figura al centro: EMUV250: visualizzazione del flusso.
Figura in basso: EMUV250: analisi CFD.

Figure above: WEATHER Project: wind loads on VAN + Trailer. Test in boundary layer simulation.
Figure in the middle: EMUV250: Filmstrip of smoke visualization.
Figure below: EMUV250: CFD calculation.

Contatti: POLITECNICO DI MILANO - DIPARTIMENTO DI MECCANICA
prof. Giorgio Diana, +39-02-2399-8423, giorgio.diana@polimi.it

Veicoli Stradali e Ferroviari

Road and Railway Vehicles

Figura in alto:
ETR 480: Simulazione dinamica dell'uscita da galleria in presenza di vento trasversale.

Figure above:
ETR 480: Tunnel exit dynamic simulationin in cross-wind conditions.

Le prove in Galleria del Vento su veicoli hanno l'obiettivo di studiare il rischio di ribaltamento associato al vento trasversale. Le forze aerodinamiche agenti sui modelli di veicoli in scala sono misurate mediante una bilancia dinamometrica a sei componenti al variare dell'angolo di incidenza (angolo tra la direzione del veicolo e della velocità del vento).

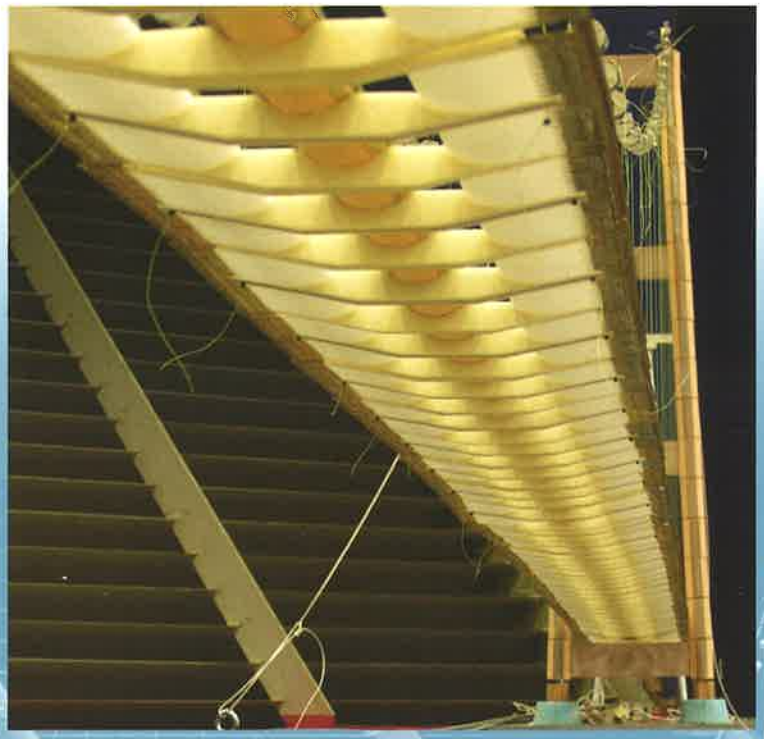
Al fine di indagare gli effetti di differenti parametri sulle caratteristiche aerodinamiche dei veicoli, i test sono realizzati in differenti condizioni di flusso (laminare o con simulazione di strato limite atmosferico), per differenti numeri di Reynolds, con scenari diversificati (viadotto, rilevato, flat ground, uscita da galleria, vedi figura in alto) e su differenti modelli di veicoli ferroviari e stradali (Pendolino, cisterna, veicoli pesanti, vedi figura in basso).

Wind tunnel tests on road/rail vehicles are aimed at evalnating the rollover risk in cross wind conditions. During the tests, the aerodynamic forces acting on the scaled vehicle models as a function of the angle of attack between the wind and the vehicle (the yaw angle) are measured by means of a six-component dynamometric balance.

In order to analyse the effects of the overall parameters on the aerodynamic forces acting on the vehicle, tests can be carried out in different atmospheric boundary layer conditions (see next page, top figure), simulating different Reynolds numbers considering several scenarios (viaduct, embankment, flat ground, tunnel exit - see top figure) and road/rail vehicle models (Pendolino train, tank, heavy vehicles, etc.- see bottom figure).

Prove su modello sezionale sospeso elasticamente ("taut-string") consentono di determinare la sensibilità dell'impalcato al forzamento da distacco di vortici e la sua risposta al vento turbolento. La misura delle forze aerodinamiche può essere inoltre effettuata tramite l'analisi del campo di pressione acquisito mediante scanner veloci multi-trasduttore. La sperimentazione su modelli aeroelastici sia della struttura completa (fino a 13.5 m di lunghezza) che delle torri portanti (fino a 3 m di altezza) viene condotta in condizioni di vento turbolento con caratteristiche opportunamente scalate per essere rappresentative delle reali condizioni operative.
Le caratteristiche dell'impianto permettono la corretta scalatura dello strato limite atmosferico e dei parametri della turbolenza naturale per differenti condizioni orografiche e di scala mediante generatori passivi di turbolenza (spires, elementi di rugosità superficiale, etc).

Tests on elastically suspended ("taut string") sectional models make it possible to analyze the deck sensitivity to vortex-induced vibrations and response to wind turbulence.
Aerodynamic forces may be also measured through analysis of the surface pressure recorded using high-speed multi-transducer pressure-scanners. Experimental tests on aeroelastic models of the full bridge itself (up to a length of 13.5 m) and of the towers (up to a height of 3 m) are performed in turbulent flow conditions with suitably scaled features representing the actual operating conditions. The wind tunnel characteristics and dimensions enable the orography of the natural boundary layer and turbulence to be scaled correctly, using passive turbulence generators, such as spires and elements roughness.



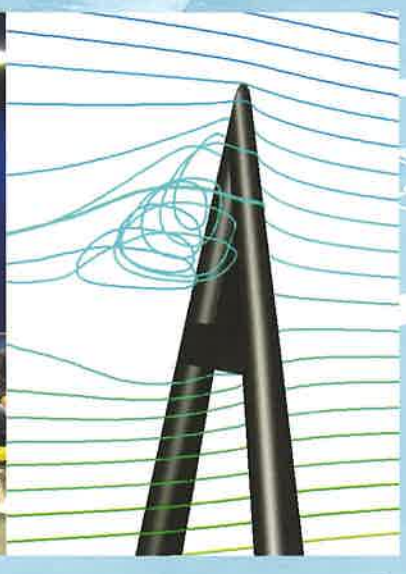


Figura in alto:
ponte sospeso sullo Stretto di Messina. Impalcato multicassone.
Figura al centro:
ponte sospeso sullo Stretto di Messina. Effetto del traffico stradale e ferroviario sul comportamento aerodinamico.
Figura in basso:
ponte strallato sul fiume Adige. Risposta aeroelastica delle torri di sostegno.

Figure above:
Messina Strait suspended bridge. Multi-box girder.
Figure in the middle:
Messina Strait suspended bridge. Effects of the road and railway traffic on the aerodynamic behavior.
Figure below:
cable-stayed bridge on Adige river. Aeroelastic response of the towers.

Contatti: POLITECNICO DI MILANO - DIPARTIMENTO DI MECCANICA
prof. Giorgio Diana, +39-02-2399-8423, giorgio.diana@polimi.it

Ponti sospesi e strallati

Suspension and cable-stayed bridges

L'analisi aerodinamica di ponti sospesi e strallati viene effettuata con prove su modelli sezionali e su modelli aeroelastici. GVPM dispone delle competenze per la progettazione e la realizzazione di tali modelli direttamente presso l'impianto. Le dimensioni della camera di prova e la disponibilità di un tavolo girevole di grande diametro (13 m) consentono l'utilizzo di modelli di grandi dimensioni con piccoli fattori di scala ed ovvi benefici in termini di Numero di Reynolds. I modelli sezionali consentono la completa caratterizzazione aerodinamica sperimentale della sezione (Coefficienti Statici, Flutter Derivatives e Funzioni di Ammettenza) mediante:

- misura delle forze aerodinamiche con bilance dinamometriche interne o esterne;
- movimentazione del modello mediante attuatori oleodinamici;
- generazione attiva di turbolenza.

The aerodynamic analysis of suspension and cable-stayed bridges is performed with tests on aeroelastic and sectional models. GVPM offers the know-how for model design and implementation directly at the facility. The dimensions of the test section and the availability of a turntable with a large diameter (13 m) facilitates the testing of very large models with small scale factor and obvious benefits in terms of Reynolds Number. Sectional models permit complete experimental aerodynamic characterization of the deck section (Steady State Coefficients, Flutter Derivatives and Aerodynamic Admittance Functions) by means of:

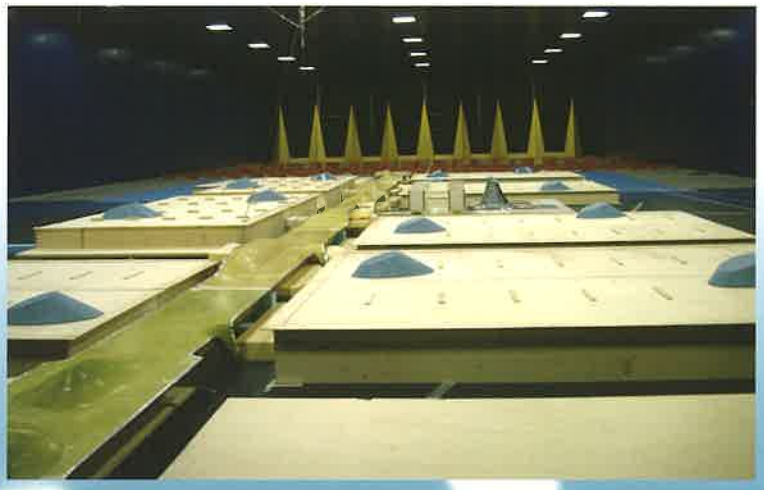
- *measurement of the aerodynamic forces with internal or external balances;*
- *model motion with oleodynamic actuators;*
- *active turbulence generation.*

Figura in alto: ponte sospeso sullo Stretto di Messina. Modello aeroelastico completo in scala 1/300.

Figure above: Messina Strait suspended bridge. 1/300 scaled full bridge aeroelastic model.

I carichi globali sono definiti usando una bilancia a sei componenti che fornisce le forze ed i momenti alla base dei modelli. Il carico sulle facciate è valutato attraverso la misura della distribuzione di pressione superficiale su modelli in scala. Utilizzando scanner di pressione veloci, sono acquisiti simultaneamente ad alta frequenza alcune centinaia di punti di misura per definire sia la componente statica che dinamica dei carichi. L'integrazione della pressione superficiale fornisce inoltre le forze globali sulla struttura. Modelli aeroelastici sono appositamente progettati per studiare gli effetti dinamici dovuti all'interazione fluido-struttura. La simulazione del vento naturale è un punto chiave nello studio degli effetti del vento stesso; tale simulazione è favorita dalle rilevanti dimensioni della camera di prova a strato limite che permette, inoltre, di condurre prove su modelli con ridotti fattori di scala (1/50÷1/200) e rilevanti dettagli geometrici.

Global wind loads are defined by using a 6 components balance that provides base force and moments on models. Cladding loads are evaluated by measuring the surface pressure distribution on scaled models. Several hundreds of points can be simultaneously sampled by using high-speed pressure scanners that define both static and dynamic loads. Integration of surface pressure distribution also provides the global forces on structures. Aeroelastic models are specially designed for studying the dynamic effects due to fluid-structure interaction. Simulation of the natural wind is a key-point for studying the effects of the wind itself. The considerable dimensions of the boundary layer test section make it possible to achieve this goal as well as to conduct tests on small scaled models (1/50÷1/200) with significant relevant geometrical features.



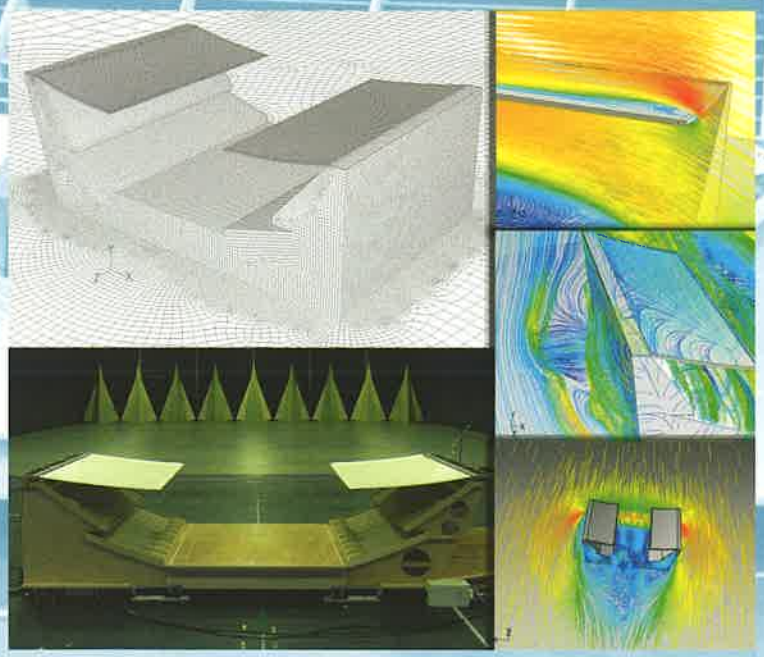


Figura in alto:
Fieramilano, Nuovo complesso a Rho. Carichi eolici su una copertura sottile e edifici bassi.
Figura al centro:
progetto CityLife, Milano. Misura della distribuzione di pressione superficiale.
Figura in basso:
Estádio Municipale de Braga, Portogallo. Comportamento aeroelastico di una copertura sospesa.

Figure above:
Fieramilano. New area in Rho. Wind loads on a thin large roof and low-rise buildings.
Figure in the middle:
CityLife project, Milan. Measurement of the surface pressure distribution.
Figure below:
Estádio Municipale de Braga, Portugal. Aeroelastic behavior of a suspended roof.

Contatti: POLITECNICO DI MILANO - DIPARTIMENTO DI MECCANICA
prof. Giorgio Diana, +39-02-2399-8423, giorgio.diana@polimi.it

Edifici e Grandi Coperture
Buildings and Large Roof Structures

Gli effetti del vento hanno significativa importanza nella progettazione delle strutture civili. Lo studio in Galleria del Vento dell'aerodinamica di strutture come edifici a grande sviluppo verticale e di grandi coperture forniscono informazioni per un'ottima progettazione e identificano possibili problemi inattesi. L'interazione fluido-struttura, infatti, può manifestare una risposta dinamica significativa che deve essere considerata. La stima del comportamento del vento nelle aree pedonali circostanti è altresì utile per l'analisi del comfort dei pedoni stessi. Studi in Galleria del Vento sono suggeriti in particolare per strutture di forma unica ed originale. Inoltre, le prove sperimentali possono essere integrate con studi numerici (CFD).

Wind effects have a significant importance in the design stage of civil structures. Wind tunnel study of the aerodynamics of structures such as tall buildings and large roofs affords data for optimum design and identifies possible unexpected wind-induced problems; in fact the interaction between fluid and structures can result in an important dynamic response that needs to be considered. The definition of wind levels in pedestrian areas is helpful for wind comfort analysis. Wind tunnel studies are especially recommended for structures with an unusual or unique shape. In addition, tests may be integrated with computational fluid-dynamic (CFD) calculations.

Figura in alto:
progetto CityLife, Milano. Studio in Galleria del Vento di edifici ad alto sviluppo verticale.

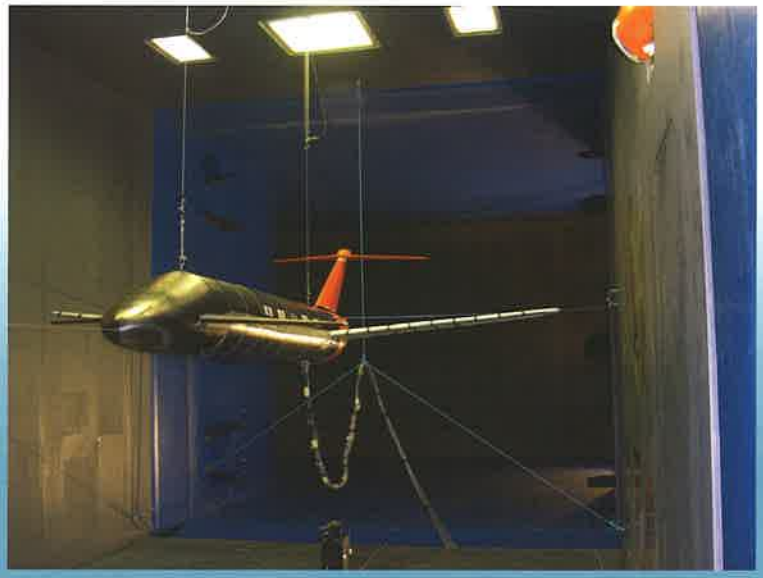
Figure above:
CityLife project, Milan. Wind tunnel study on high-rise buildings.





La Galleria è dotata di un sistema di misura di pressione multicanale, per il rilievo della distribuzione di pressione sulla superficie del modello, e di numerosi sensori miniaturizzati per il rilievo dinamico di pressioni con elevatissima frequenza di campionamento.
Rilievi di scia possono essere effettuati sia con sonde direzionali (sonde di pressione multiforo e sonde a filo caldo triplo) sia con tecniche di tipo ottico (LDA e PIV).
E' disponibile un sistema di aspirazione controllato in portata (sia volumica sia massica) per simulare l'aspirazione del compressore nei test di prestazione delle prese d'aria.
Un sistema di telecamere permette di monitorare e registrare le prove. Telecamere ad alta velocità possono essere utilizzate per riprendere fenomeni molto rapidi (quali per esempio l'apertura di un paracadute freno).
I modelli per prove dinamiche e aeroelastiche possono essere vincolati in modo non rigido con una opportuna sospensione a cavi.

Wind tunnel is supplied whit multiport pressure measuring system well suited to measure pressure distribution on model surface and with several high frequency miniaturized pressure sensors. It's possible to perform wake survey using both directional probes (multihole pressure probes or three components hot wire probes) and optical techniques (LDA or PIV).
There is a suction system (controlled both in volume and mass flow rate) to simulate compressor suction during air intakes testing.
Some digital cameras are used as a security monitor and to produce an image recording of the tests. High velocity cameras are available to record images of high velocity phenomenons.
Aeroelastic and dynamically scaled models are supported by the means of a flexible suspension.



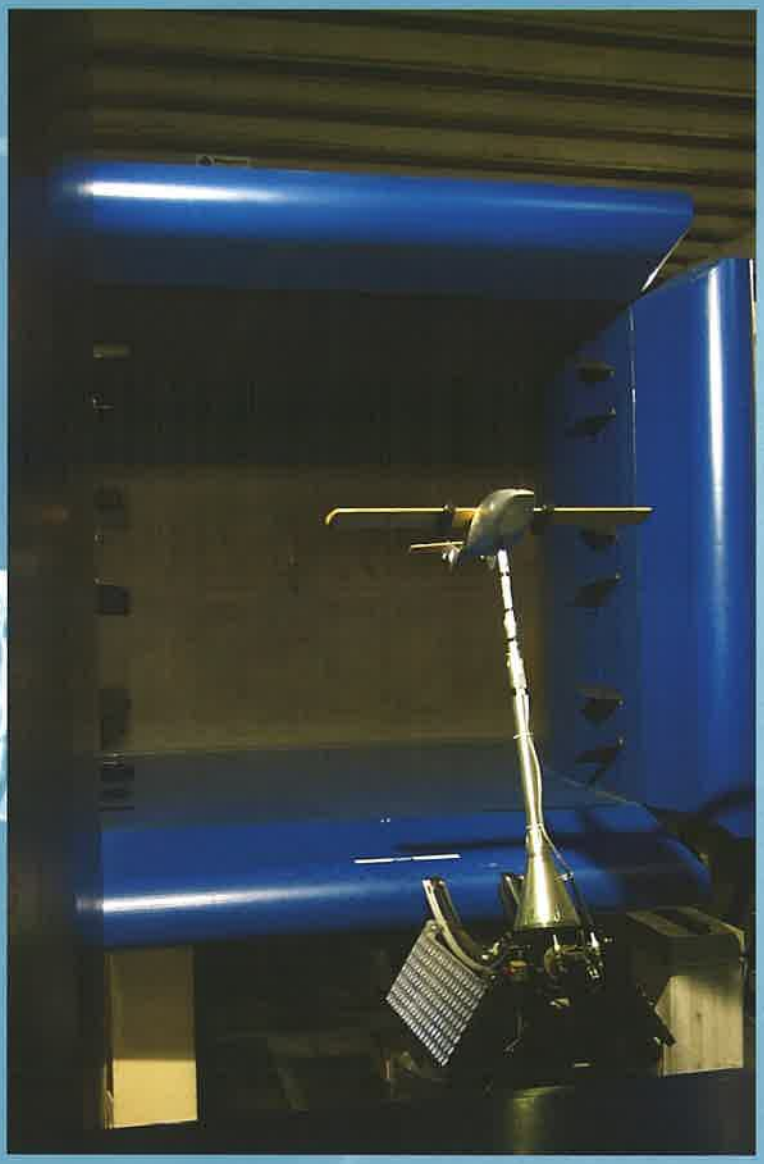


Figura in alto: sospensione a cavi del modello aeroelastico X-DIA per prove dinamiche nella camera di prova chiusa.
Figura in basso: rilievi in camera di prova aperta dei coefficienti aerodinamici del velivolo OMA Sud Skycar.

Figure above: X-DIA aeroelastic model on cable mount inside the closed test section during dynamic testing.
Figure below: measurement of OMA Sud Skycar aerodinamic coefficients in open test section.

Contatti: POLITECNICO DI MILANO - DIPARTIMENTO DI INGEGNERIA AEROSPAZIALE
prof. Giuseppe Gibertini, +39-02-2399-8389, gibertini@aero.polimi.it

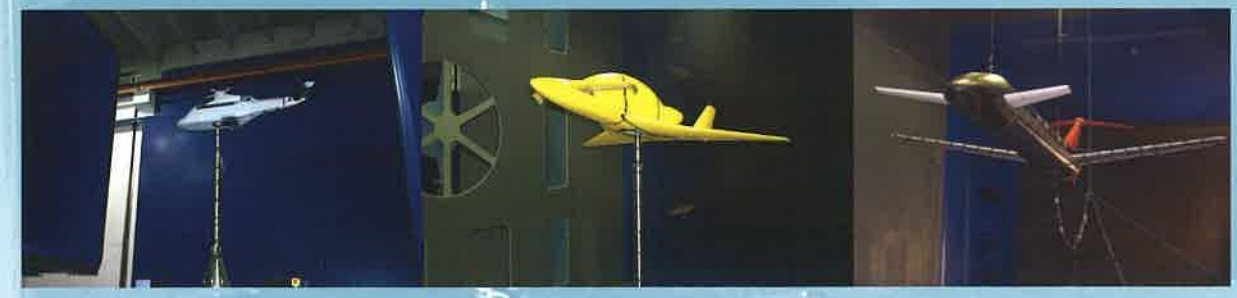
Applicazioni Aeronautiche
Aeronautical Testing

La Galleria del Vento del Politecnico di Milano offre una vasta gamma di possibili prove di ambito aeronautico.
La Galleria è dotata di bilance interne a sei componenti di diverse dimensioni e fondo scala. Una apposita bilancia può essere alloggiata sotto il pavimento per le prove su "semimodelli". La Galleria, inoltre, è completamente equipaggiata con la più moderna strumentazione per rilevare la pressione (anche non stazionaria) sulla superficie del modello e per condurre rilievi di pressione e velocità nelle scie.
I modelli possono essere montati su diversi tipi di piloni, sia in camera chiusa sia in camera aperta. La prova in camera aperta è particolarmente indicata per i rotori di elicottero.

Politecnico di Milano Wind Tunnel offers a wide range of aeronautical testing applications. The wind tunnel is supplied with various six components internal balances of different dimensions and loads. It's possible to perform half model tests using a dedicated balance installed under the floor of the test chamber.
The wind tunnel is completely equipped with up-to-date instrumentation that allows for steady and unsteady wall pressure measurements and for pressure and velocity survey in the model wake.
Several model supporting systems are available both in closed and open test section.
Open jet wind tunnel configuration is well suited for helicopter rotor testing.

Figura in alto:
preparazione del modello di fusoliera di un elicottero Agusta-Westland per rilievi di pressione nei condotti di aspirazione.

Figure above:
model installation of Agusta-Westland helicopter for air intakes pressure measurements inside the closed test section.



Case History

Stretto di Messina
Progettazione aerodinamica del Ponte sullo Stretto di Messina.
Aerodynamic design of the Messina Strait Bridge.

Agusta Westland
Prove su modelli in scala e su componenti reali di elicotteri.
Wind tunnel tests of helicopter scaled models and real scale components.

Trenitalia
Fluidodinamica sperimentale e computazionale di veicoli ferroviari e determinazione delle Critical Wind Curves (CWC).
Experimental and computational aerodynamic analysis of railway vehicles and evaluation of the Critical Wind Curves (CWC).

Coni Servizi
Prove in Galleria del Vento per la squadra olimpica di slittino.
Wind tunnel tests on behalf of Italian olympic luge team.

RFI Rete Ferroviaria Italiana
Calcolo delle Critical Wind Curves (CWC) di veicoli ferroviari in differenti siti/scenari.
Evaluation of the Critical Wind Curves (CWC) of railway vehicles for different sites/scenarios.

AnsaldoBreda
Studio aerodinamico di veicoli ferroviari finalizzato all'ottimizzazione della geometria.
Aerodynamic analysis of railway vehicles aimed at the optimisation of their geometry.

Luna Rossa
Fluidodinamica sperimentale e numerica di imbarcazioni a vela classe Coppa America.
Experimental and Numerical Aerodynamic study for an America's Cup sailing yacht.

ORC
Fluidodinamica sperimentale e numerica per il sistema di stazza internazionale (IMS) di imbarcazioni a vela.
Experimental and Numerical Aerodynamic Study for the International Measurement System (IMS) of sailing yacht.

Maire Engineering
Aeroelastica della copertura della Pinacoteca del Lingotto a Torino (Tappeto Volante).
Aeroelasticity of the roof of the Picture-gallery over the Lingotto in Turin (Flying Carpet).

Vulcanair
Prova delle prese statiche di aspirazione del velivolo Mission.
Wind tunnel tests of Mission aircraft's air intakes.

Selex
Prove in Galleria del Vento del paracadute di recupero dell'UAV Falco.
Wind tunnel tests of recovery parachute of Falco UAV.

Oma Sud
Prove aerodinamiche del velivolo Skycar.
Aerodynamic tests of Skycar aircraft.

CityLife
Riqualificazione del quartiere storico dell'area Fiera di Milano (Architetti Z. Hadid, A. Isozaki, D. Libeskind e P.P. Maggiora).
Requalification of the historical site of the Trade Fair in Milan (Architects Z. Hadid, A. Isozaki, D. Libeskind e P.P. Maggiora).

Redaelli Tecna
Caratterizzazione aeroelastica della copertura sospesa dello stadio di Braga (Portogallo).
Aeroelastic behaviour of the suspended roof of the Braga stadium (Portugal).

Salvi
Prove sui dispositivi smorzanti per il controllo delle vibrazioni eoliche sui cavi.
Tests on damping devices designed for cable aeolinan vibrations control.

Caratteristiche delle sezioni di prova
Sezione a Strato Limite - Sezione Aeronautica

Test Section Performances
Boundary Layer Test Section - Aeronautical Test Section

La scelta del layout verticale e l'adozione per il divergente di una soluzione tipo "wide angle diffuser" con controllo di separazione a valle della camera di prova aeronautica hanno consentito la realizzazione di un impianto estremamente compatto, con vantaggiose ripercussioni in termini di grandissima versatilità nella tipologia di prove offerte e di economicità ed efficienza di gestione.

Il ramo superiore del circuito ospita la sezione di prova a strato limite (14x4m, VMax=16m/s, IT<2%), con possibilità di simulazione dello strato limite caratteristico del vento terrestre (IT>25%), grazie al grande sviluppo longitudinale (L=35m). Peculiarità di questa sezione è la dotazione di un tavolo girevole su cuscino d'aria, di diametro pari a D=13m, integrato nel pavimento con possibilità di allestimento di modelli complessi (carico Max pari a 100000N) e gestione automatizzata del cambio di direzione di esposizione al vento.

La camera di prova aeronautica, il ramo inferiore del circuito, ha una sezione di 4m x 3,84m x 6m (larghezza x altezza x lunghezza) con la possibilità di effettuare prove sia in camera chiusa sia in getto libero. La velocità massima del vento è di 55 m/s con un livello di turbolenza inferiore allo 0,1%. Esistono due camere di prova chiuse intercambiabili. É possibile quindi allestire una nuova prova durante il funzionamento dell'impianto.

Ciascuna camera è dotata di un piano rotante circolare del diametro di 2,5m e di un sistema di traversi che permette di movimentare una sonda a valle del modello per effettuare rilievi di scia. Sono disponibili diverse tipologie di supporti per i modelli, dotati di sistemi di movimentazione per variare l'angolo di incidenza.

The vertical layout configuration, together with the "wide angle" diffuser and separation control devices following the high-speed test section, had been selected in order to obtain a compact design.

The smart design and engineering of the GVPM make it possible to offer a very wide-ranging test possibility and to achieve a substantial running economy.

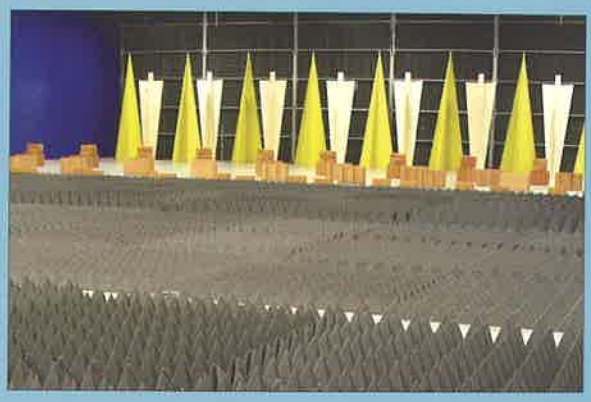
The upper leg of the loop hosts the Boundary Layer Test Section (section 14m x 4m, max wind velocity: 16m/s, turbulence index <2%). The 35m long, constant section test room enables the setting up of upstream active or passive turbulence generators to simulate the atmospheric boundary layer (turbulence index >25%).

The model to be tested, together with the related environment, is set up on a 13m diameter turntable, included in the wind tunnel floor to permit computer pre-selected wind incidence angle change. The max load on the turntable can stand 100000N.

The aeronautical test section, the lower leg of the loop, is 4m wide, 3.84m high, and 6m long. It is possible to perform tests in a closed test section and in an open jet.

The maximum wind velocity is 55m/s and the turbulence level is less than 0.1%. There are two interchangeable closed test sections; it is thus possible to prepare a new experiment while the wind tunnel is running.

Both closed test sections are equipped with a turntable (diameter 2.5m) and a traversing system behind the model's location, suitable for making wake measurements. There are several model supports equipped with a positioning system in order to vary the incidence angle.



In alto:
la camera di prova a strato limite per le applicazioni civili ed ambientali.

In basso:
la camera di prova a bassa turbolenza e alta velocità per le applicazioni aeronautiche.

Above:
the boundary layer test section used for civil and environmental applications.

Below:
the high-speed low turbulence test section used for aeronautical purposes.

La gestione della Galleria del Vento del Politecnico di Milano (GVPM) è coordinata dal CIRIVE, Centro di Ricerca sull'Ingegneria del Vento, che si colloca nell'Area Ricerca e Trasferimento Tecnologico - Servizio Grandi Infrastrutture del Politecnico di Milano. Il CIRIVE ha diretto le attività di progettazione e realizzazione dell'impianto in collaborazione con i Dipartimenti di Meccanica, Aerospaziale, Energetica, Strutturale, Elettronica-Informazione e Diiar (Idraulica, Ambientale, Infrastrutture Viarie, Rilevamento). Attualmente il CIRIVE è responsabile, oltre che della gestione, anche della continuativa attività di sviluppo di nuove tecnologie di misura e di analisi a servizio delle prove in Galleria del Vento.
Essendo l'Ingegneria del Vento di carattere tipicamente interdisciplinare, è finalità del CIRIVE favorire l'integrazione e lo scambio tra le diverse competenze e settori di ricerca specifici, quali quello aeronautico, strutturale, meccanico, energetico, ambientale ed architettonico.
Il Centro coordina attività finalizzate a promuovere e divulgare le ricerche e gli studi nel settore dell'Ingegneria del Vento, sia con intendimenti innovativi di ricerca scientifica, sia allo scopo di riportare tale esperienza in ambito didattico, favorendo iniziative coordinate per l'inserimento di tale disciplina nei curricula ingegneristici più idonei.

The management of GVPM is co-ordinated by CIRIVE, Research Centre on Wind Engineering, belonging to the Area "Research and Technology Transfer - Large Infrastructure Service" of Politecnico di Milano. In co-operation with the Departements of Mechanics, Aerospace, Energetics, Structural, Electronics and Information, and Diiar (Hydraulics, Environmental, Infrastructures and Survey Engineering) of the Politecnico di Milano, CIRIVE was in charge of the planning and construction of the facility. It now manages the GVPM and develops new measuring and analysis technology for the Wind Tunnel tests.
CIRIVE aims to distribute the integration and the exchange among different skills and types of scientific researches, for example aeronautics, structural, mechanics, environmental and architectural.
CIRIVE manages activities aimed at the promotion and spread wind engineering research. The object is to propagate this knowledge, thus creating a teaching method and inspiring an innovation research plan with the aim of adding this subject in the more suitable engineering curricula.

Contatti

GVPM - Galleria del Vento - Politecnico Milano
E.Mail: windtunnel@polimi.it
Sito Web: www.windtunnel.polimi.it
Direttore del centro: Prof. Giorgio Diana
E-mail: giorgio.diana@polimi.it

Sede:
Campus Bovisa Sud
Via La Masa 34 - 20156 Milano, Italia

Direzione Amministrativa:
Tel +39-02-2399-8073
Fax +39-02-2399-8081

Area Tecnica:
Ingegneria del Vento
Tel +39-02-2399-8074
Fax +39-02-2399-8081
Aeronautica
Tel +39-02-2399-8086
Fax +39-02-2399-8081