SUSTAINABLE CONSTRUCTION

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Praha 2011

Cover design: MgA. Tereza Višinková
Photo source: Prof. Ing. Ivan Vaníček, DrSc.

Editor's note

The publication contains a set of mutually supplementing works, which are devoted to the State of the Art in the area of Sustainable Construction. The authors of individual chapters are not only members of the research team solving research grant of the same name supported by the Czech ministry of Education (MSM 6840770005) but also invited domestic and foreign experts.

Title: Sustainable Construction

Editor: Prof. Ing. Ivan Vaníček, DrSc.

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Publisher: Czech Technical University in Prague
Press: Česká technika – nakladatelství ČVUT
Publisher address: Thakurova str. 1, 160 41 Prague 6, Czech Republic
Number of pages: 163
Circulation: 300
Edition: 1
Contact address: CTU in Prague Faculty of Civil Engineering, Geotechnical Department; Dr. Daniel Jirásko, e-mail: daniel.jirasko@fsv.cvut.cz

ISBN 978-80-01-04873-3

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Udržitelná výstavba

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Vážený pane rektore, vážená paní děkanko, vážení hosté, dámy a pánové,!

Děkuji za pozvání na dnešní mezinárodní konferenci věnovanou udržitelné výstavbě. Oceňuji, že se bude zabývat tématem, které hraje, lépe řečeno – mělo by hrát - nezastupitelnou roli v prioritách národních programů udržitelného rozvoje, v programech vědeckých, výzkumných a vývojových ústavů, na akademické půdě, samozřejmě také u architektů, projektantů, developerů, zadavatelů a investorů staveb a u široké dodavatelské sféry, ale také by mělo již konečně oslovit orgány státní správy, ministerstev a vládu naší republiky.
Současná finanční a ekonomická krize nastala v době, do níž se promítly důsledky několika paralelně dlouhodobě probíhajících jevů:

- globalizace
- demografická exploze v rozvojových zemích
- neobyčejně rychlý růst ekonomik velkých rozvojových zemí jako jsou Čína, Indie, Brazílie a další, s jejich rychle rostoucí potřebou zdrojů energie a surovin, ale i důsledky na znečišťování ovzduší a vod
- informační exploze
- rostoucí míra urbanizace, která vede k růstu satelitních měst s vysokými požadavky na zábor půdy, dopravu a finanční zdroje
- růst rychlosti ubývání přírodních zdrojů, způsobený plýtvavým charakterem soudobého fungování vyspělých ekonomik
- celoplanetární klimatické důsledky stávajícího výrobního způsobu, založeného na vysoce nehospodárném využívání neobnovitelných zdrojů energie, zejména fosilních paliv
- nevhodný ekonomický mechanismus, který neodráží v tvorbě cen náklady související se škodami na životním prostředí a který činí ekonomicky efektivním i ničení životního prostředí.

Je zcela zřetelné, a není to náhodou, že většina z těchto faktorů zákonitě velmi intenzivně působí proti základním principům udržitelného rozvoje společnosti. Pojem, který je v ČR stále na okraji zájmu – „trvale udržitelné stavění" - se v krátké budoucnosti musí stát klíčovým pro rozvoj celého odvětví a ovlivní uvažování a chování všech podnikatelských subjektů. Objevuje se stále častěji v různých analýzách a prognózách, for-

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málně i věcně navazuje na obecnější pojem "udržitelný rozvoj". Jestliže u trvale udržitelného rozvoje je smysl i cíl poměrně jasný, u stavění to prozatím ve všeobecnou známost ani povědomí nevešlo.

Země Evropské unie v roce 2007 podepsaly dohodu o vyhlášení řady programů, které jsou závazné a vyžadují od členských zemí splnění stanovených limitů a hodnot ve stanovených termínech do roku 2020 a 2050.
Naléhavost úkolů trvale udržitelného rozvoje vedla orgány EU k vypracování společné strategie výzkumu pro evropský stavební průmysl do roku 2030, orientující země EU k přípravě a zabezpečení cílů, stanovených a dohodnutých při schvalování Lisabonské smlouvy. Rozhodující jsou opatření v úsporách energie, snížení emisí škodlivých plynů a náhradě klasických zdrojů energie obnovitelnými. Toho lze vzhledem k rozsahu stávajících stavebních fondů docílit jak v nové výstavbě, především ale v rekonstrukcích a modernizaci těchto fondů – zejména budov, které spotřebovávají až 40% veškeré vyrobené energie o zodpovídají přibližně za 36% emisí skleníkových plynů. Strategie je pro členské země závazná a vyžaduje od nich splnění stanovených limitů a hodnot. Platí tedy i pro naši republiku.
Protože pouhé stanovení limitů není dostatečným opatřením k zabezpečení realizace úspor, přikročily vlády řady evropských zemí v uplynulých letech k rozsáhlým investicím a motivaci v této oblasti, jakož i k účinné mezinárodní spolupráci. Většina zemí s vyspělým stavebnictvím (Velká Británie, Francie, Německo, Švédsko a další země) vyhlásily vládní nebo rezortní programy pro oblast udržitelného stavění, jejichž realizace má zajistit splnění uvedených cílů, obsahujících zcela konkrétní termínovaná opatření i způsob jejich financování a kontroly. Vládní opatření vycházejí z poznatku, že nejúčinnější jsou ta opatření, která mají charakter podnikatelský, to jest taková, která jsou pro všechny účastníky finančně výhodná. Znamená to důraz na přednostní využití forem ekonomické stimulace. Získá se tím zájem a potřebný objem investic od podnikatelů a domácností.
Nedílnou součástí přípravy a realizace celého procesu je včasné, finančně i odborně náročné informační zabezpečení. O tom svědčí desítky workshopů, seminářů a informačních kampaní, pořádaných pro odbornou veřejnost, stavební dodavatelské firmy. Rovněž denní tisk a televizní či rozhlasové vysílání a dokonce specializované programy hlavních veřejnoprávních médií informují trvale veřejnost o problémech, novinkách, úspěšném řešení dílčích problémů udržitelné výstavby s příklady staveb i výrobků, ale i výstavby či rehabilitace celých městských čtvrtí, jejichž cílem je poskytnutí informací široké veřejnosti a získání podpory stávajících i budoucích uživatelů staveb pro udržitelné stavění. Kromě potřebné a důležité informovanosti je významným produktem i vytváření příznivého dojmu o stavebnictví. Právě takový synergický efekt by trvale přispíval i našemu v současné době médii nedobře prezentovanému stavebnictví.
Evropský parlament ve Štrasburku přijal na svém zasedání 15. prosince loňského roku Usnesení k revizi akčního plánu pro energetickou náročnost. Ukládá v něm, jaká opatření mají být přijata výkonnými orgány EU a národními vládami v nejbližší době v oblasti udržitelné výstavby v kapitolách: Soulad se stávajícími právními předpisy, Energetická infrastruktura, Rozvoj měst a budov, Informační a komunikační technologie, Doprava, Pobídky a financování. Očekáváme s napětím, která instituce nebo orgán se tohoto úkolu u nás zhostí.

Vypracování, projednání, schválení a realizace vládních programů představuje obrovské úsilí a úzkou spolupráci řady orgánů státní správy, územních orgánů, odborných kapacit sdružených v SIA – Rada výstavby (ČKAIT, ČSSI, ČKA, SPS, Asociace konzultačních inženýrů a další), společně s developery , hlavními výrobci stavebních hmot a výrobků pro stavby, zástupci měst a obcí, architektonických a projektových ateliérů a dalšími partnery ve výstavbě.

V organizační struktuře MPO po několik let neexistoval útvar stavebnictví, i když je toto ministerstvo jako jediný vládní orgán podle platného kompetenčního zákona odpovědné za oblast stavebnictví a výroby stavebních hmot. Žádný z jeho útvarů nemá potřebné informace a tudíž je ani nemůže poskytovat a nést odpovědnost za neblahý stav v této oblasti. Z toho plyne naprostá neznalost hlavních cílů a směrů vývoje evropského stavebnictví i návazných oborů, trvale klesající rozsah výzkumných kapacit odvětví stavebnictví, jakož i nedostatek finančních prostředků na zabezpečení takových prací externími kapacitami. Dalším důsledkem je pak i nedostatek koordinace činnosti více resortů, podílejících se na výstavbě, stejně jako využití specializovaných a nevládních organizací v odvětví. Česká republika má v oblasti udržitelné výstavby za vyspělými zeměmi několikaleté zpoždění a naléhavost této otázky nebyla dosud kompetentními místy pochopena. Důsledky pro budoucí konkurenceschopnost odvětví není obtížné dohlédnout.

O problematice udržitelné výstavby nejsou zatím české nevládní odvětvové organizace informovány ministerstvem, nýbrž kolegy z jiných zemí při společném jednání nevládních organizací (FIEC) a při osobních jednáních s pracovníky zahraničních rezortů, do jejichž působnosti oblast stavebnictví patří.

O existenci programů udržitelné výstavby iniciovaných a financovaných vládními orgány příslušných zemí EU považovali za nutné informovat českou stavební veřejnost představitelé nevládních organizací ve stavebnictví, především SPS. Informace o francouzských programech přednesli na žádost Svazu podnikatelů ve stavebnictví přední francouzští odborníci a tomuto tématu byl věnován Francouzský den v rámci Stavebního veletrhu v Brně v roce 2008, na který byli pozváni představitelé českých ústředních i územních orgánů. Semináře se zúčastnila řada odborníků z praxe, oblasti vědy a výzkumu, územních orgánů a několika ministerstev (nikoli však zástupce MPO) a byl pro převážnou většinu účastníků zatím jediným zdrojem relevantních informací.
U nás neexistuje žádný dokument k udržitelné výstavbě, ačkoli SPS již dva roky jedná s věcně příslušnými resorty o jeho potřebě. Ten by měl s využitím poznatků vládních dokumentů zemí západní Evropy vyhlásit cíle, formy a výši podpory státu a sjednotit úsilí státních a územních orgánů, podnikatelských kruhů, ale i vědeckých a výzkumných pracovišť, škol a učilišť a zabezpečit informování široké veřejnosti.
Vláda ČR schválila v lednu 2010 aktualizaci Strategie udržitelného rozvoje nazvanou Strategický rámec udržitelného rozvoje, k níž v průběhu přípravy dokumentu vyjádřil konstruktivní připomínky i SPS ve smyslu potřeby konkretizace a uložení úkolů příslušným odpovědným resortům s využitím poznatků zahraničních dokumentů a jejich několikaletého předstihu v této oblasti.
V české ekonomice - podobně jako v dalších zemích EU - dojde v nejbližších letech k zásadním strukturálním změnám, s významnými důsledky pro stavebnictví. Svaz podnikatelů ve stavebnictví ve své publikaci Vývoj stavebnictví do roku 2012 věnuje kapi-

tolu dlouholeté vizi stavebnictví a návrhům opatření pro rozvoj odvětví stavebnictví v České republice po odeznění ekonomické krize.
V souvislosti se změnou struktury poptávky se masivně prosadí nové progresivní materiály a stavební prvky, podporované využitím moderních technologií. Dojde k zefektivnění stavební výroby a změně manažerských přístupů směrem ke konceptu „štíhlého stavebnictví“.
Rozsáhlé investice budou směřovat k úsporám ve spotřebě energie a dalších přírodních zdrojů, k výstavbě kapacit souvisejících s obnovitelnými zdroji, návratu k jaderné energetice, k vytvoření lodní dopravní cesty propojením Dunaje, Odry a Labe a omezení přeprav zboží i osob a přesunu silniční dopravy na železnici, k obnovení režimů vodního hospodářství využívajícího někdejších přírodních způsobů regulace, k budování inteligentních sítí energetických přenosových soustav, k rozsáhlé rehabilitaci bytového fondu, k vyšší míře recyklace materiálů. Ze systémového hlediska se bude jednat o přijetí důsledných opatření ke zvýšení soběstačnosti menších celků, ale současně pokračování integračních procesů na té úrovni, kde jsou takové procesy žádoucí nebo dokonce nezbytné.
Dojde k přehodnocení současných územních a urbanistických koncepcí, to vše s cílem podstatného snížení objemu, vzdáleností a energetické náročnosti přepravy nákladů i osob, snížení spotřeby surovin a energie, výrazného prodloužení životnosti výrobků a staveb, předcházení vzniku poruch a havárií ale i omezení vlivu nepředvídatelných jevů na hospodářský i civilní život obyvatel. Příkladů lze již dnes v Evropě nalézt v nejrůznějších oborech nesčetné množství, často s využitím odlišných řešení téhož problému v souvislosti s rozdílnými podmínkami daného místa. Odtud plyne i potřeba individuálního přístupu v území nebo odvětví.
Převážná většina prací souvisejících s realizací změn bude vyžadovat stále kvalifikovanější pracovní sílu, které stavebnictví již dnes pociťuje v Evropě značný nedostatek - v řádu desítek tisíc pracovníků v jednotlivých zemích a celkově několik set tisíc osob. Za předpokladu, že nebude včas přijato do učebního poměru a vyškoleno dostatečné množství mladých pracovníků, nebudou stavebním firmám moci být zadávány zakázky, neboť podmínky zadavatelů pro kvalitativně náročnější stavby z hodnotnějších a tedy dražších materiálů a komponentů se budou trvale zpřísňovat.

Stavební podnikatelé vnímají udržitelné stavění jako nový rámec civilizačního rozvoje, který může být udržitelný tehdy, naplní-li potřeby současné generace, aniž by ohrozil možnosti naplnit potřeby generací příštích.

Pro stavební společnosti jsou důležité dva aspekty: enviromentální limity a ekonomické a sociální limity, vyplývající ze zvyšujících se konkurenčních tlaků. Manažéři počínají zvolna vnímat, že jim „zelené iniciativy“ mohou přinést konkurenční výhodu. Výhrou bude, až jim budou tuto výhodu opravdu přinášet, protože osvícených investorů je prozatím velmi poskrovnu. Jejich prioritou je především pořizovací cena a nikoli nalézání zdokonalených řešení staveb, která zajistí ekonomickou výhodnost, budou prospěšná společnosti a ohleduplná k životnímu prostředí.

Filozofie rozvoje firem v konceptu udržitelného rozvoje musí směřovat ke klientům a partnerům v pěstování vztahů, založených na vzájemném naslouchání, důvěře a transparentnosti. Firma musí mít zodpovědný přístup k vlastním zaměstnancům v oblasti bezpečnosti, zdraví a rozvoje znalostí Také musí být vstřícná k regionům, účastnit se na ekonomickém a sociálním životě v místech svého podnikání. V oblasti podpory životního prostředí a inovací musí podporovat ekologická řešení při projektování staveb, snižovat environmentální dopady stavenišť. Znamená to ekologicky šetrné provádění stavby a právě tak ekologicky šetrné zařízení staveniště, provozované jako „zelená budova“.

Udržitelné stavění je nutno vnímat také jako základ stability národní ekonomiky. Na prvním místě by měla být vize budoucího směrování státu, kterou dlouhodobě postrádáme. Z ní by mělo být patrné, z čeho bude generovat příjmy a co bude přidaná hodnota, kterou můžeme a chceme nabídnout. Na to musí navazovat dílčí koncepce a rozhodnutí, jaké investice jsou nutné a potřebné k dosažení těchto příjmů, kdy si je stát může dovolit a jak je bude financovat. Za předpokladu, že daná investice má jasně spočítané efekty, je možné i její dluhové financování. Stát si musí uvědomit svou výlučnou pozici coby největšího a nejsilnějšího investora a zákazníka pro stavebnictví a jeho ekonomický význam. Měl by svoji investiční koncepci stavět jako proticyklickou, nikoli procyklickou.

Budoucnost stavebnictví je závislá nejen na vývoji ekonomiky, ale také na tom, zda vláda bude považovat veřejné investice za účinný přírůstový a proticyklický nástroj. Klíčové je zajištění plynulosti, neboť výkyvy v poptávce vedou zejména k vytváření nadbytečných kapacit nebo naopak k jejich nedostatku. Jde o kapacity personální, ale i technického vybavení. Stát jako největší investor stavebních zakázek má nezastupitelnou roli ve vytváření stabilizačního efektu. Musí dlouhodobě plánovat, aby stabilizoval poptávku na trvale (dlouhodobě) udržitelné úrovni. Při tom nesmí opomenout pozitivní, ale zejména i negativní účinek vysokého multiplikačního efektu stavebnictví. Udržitelné stavění tedy z tohoto velmi důležitého úhlu pohledu znamená návrat k přiměřenosti.

Řekl jsem v úvodu, že Česká republika má v oblasti udržitelné výstavby za vyspělými zeměmi několikaleté zpoždění. Co by se mělo urychleně udělat, abychom se pokusili alespoň částečně dohnat tento evidentní skluz.

- Nejprve je nutné, aby se vláda seznámila se skutečným stavem věcí, pochopila nutnost změny směrování a vývoje pokroku a uvědomila si naše zaostávání za světem.

- Je nezbytné seznámit odbornou i občanskou veřejnost se stavem v jakém se nacházíme ve srovnání s námi přijatými společnými požadavky EU, stavem ve vyspělých zemích, a reálnými potřebami národní ekonomiky i ekologie v příštích letech.

- Nechat zpracovat a vyhlásit program udržitelné výstavby se stanovením cílů, prostředků a cest vedoucích k jejich dosažení. (Za spolupráce s nevládními organizacemi,. vysokými školami, výzkumnými kapacitami zabývajícími se problematikou udržitelné výstavbě a dalšími – zejména urbanisty, architekty, územními orgány, výrobci a stavebními firmami.)

- Informovat veřejnost o způsobech, jakými vláda ve spolupráci s nevládními orgány a organizacemi hodlá tyto cíle zabezpečit (nikoli hesly a dalšími nic neříkajícími dokumenty, ale konkrétními opatřeními a definovat jejich důsledky pro podnikatelskou sféru, domácnosti, obce, výrobce, spotřebitele, atd.)

- Podobně jako to činí vlády vyspělých zemí již řadu let zajistit informační osvětu o smyslu programů, jejich plnění, důsledcích v národním i mezinárodním kontextu.

Lze vyslovit osobní závěr , že podobně jak ukazují zahraniční zkušenosti, bez okamžitého impulsu vlády ČR, který by vyhlásil, zkoordinoval a usměrnil za pomoci značné finanční podpory program udržitelného stavění, se nemůže podařit dílčími opatřeními docílit ani potřebné spolupráce těch, kdo se na programu budou muset podílet, ale ani žádoucích výsledků.
Svaz podnikatelů ve stavebnictví, vědom si důležitosti problematiky udržitelné výstavby, nezůstává stranou snahy o prosazení jejích principů. Již před rokem jsme vyhlásili iniciativu zřízení Centra udržitelné výstavby v Brně. Jeho provozovatelem se stává Národní stavební centrum Svazu podnikatelů ve stavebnictví.
V dubnu 2010, v průběhu Stavebních veletrhů Brno, došlo k podpisu memoranda o spolupráci při zřízení Centra udržitelné výstavby. Svůj podpis připojil hejtman Jihomoravského kraje, ředitel Státního fondu životního prostředí, rektor Vysokého učení technického v Brně, generální ředitel společnosti Veletrhy Brno a zástupci SPS a Národního stavebního centra.
Později byla předjednána spolupráce se stavební fakultou ČVUT a se stavební fakultou technické univerzity v Ostravě. Podporu projektu vyslovil Český svaz stavebních inženýrů i zástupci inženýrských komor zemí Visegradské čtyřky. Pro realizaci projektu hledáme podporu u zástupců státní správy, jakkoli je to v současné politické situaci obtížné. Záměr vychází z inspirace, dané fungováním obdobných center ve vyspělé Evropě, sdružených ve světové unii UICB.
Centrum je zaměřeno na vzdělávání jak odborné, tak laické veřejnosti a na prezentaci soudobých materiálů a technologií pro realizaci staveb. Má zvýšit povědomí uživatelů staveb a soukromých i veřejných investorů o problematice trvale udržitelného rozvoje ve stavebnictví, přispět k poznávání ekologicky a energeticky méně náročných materiálů, technologií a výrobků, používaných jak při rekonstrukcí staveb, tak v nové výstavbě. Smyslem je podpora snižování energetické náročnosti stavebního díla v celém jeho životním cyklu (projekce → realizace → provoz → likvidace). Jsme přesvědčeni, že naše iniciativa přispěje k posílení filozofie udržitelné výstavby jak v tuzemském měřítku, tak v kontextu mezinárodním.
Na závěr bych rád vyslovil naději, že i v naší republice najde udržitelné stavění nejen své přesvědčené propagátory, ale hlavně ty, kteří jim budou chtět naslouchat a také jim rozumět. Věřím, že dnešní konference k tomu významně napomůže.

Ing. Václav Matyáš
prezident SPS ČR

Sustainable Construction

V. Matyáš
President of the Association of Building Entrepreneurs of the Czech Republic

Dear Mr. Rector, dear Mrs. Dean, Dear guests, ladies and gentlemen!

Allow me to thank you for your invitation to today's international conference on sustainable construction. I appreciate that it will deal with a topic that is, better to say – that should be - irreplaceable within priorities of national programmes of sustainable development, in programmes of scientific, research, and development institutes, for academia, also for architects, designers, developers, construction contractors and investors, and the whole supply sector. Last but not least, it should appeal to the state administration, ministries and the Czech government.
The current financial and economic crisis started at the time when consequences of several parallel phenomena were taking place over a long period of time:

- globalization
- demographic explosion in developing countries
- unusually fast growth of economies of large developed countries, such as China, India, Brazil and others, leading to quickly rising need of energy and raw materials, as well as air and water pollution
- information explosion
- increasing rate of urbanization that brings about growth of satellite towns with high demands on land take, transport and financial sources
- increase of the speed of consumption of natural resources caused by wasteful nature of current performance of developed economies
- planetary climatic consequences of the existing production methods based on highly uneconomic exploitation of non-renewable energy sources, especially fossil fuels
- unsuitable economic mechanism that does not reflect, in pricing, costs connected with impacts on the living environment and that makes even damage to the environment economically effective.

Obviously and it is not coincidental, most of these factors inevitably work against fundamental principles of sustainable development of the society in a highly intensive manner.
The concept, which is still of marginal importance in the Czech Republic – sustainable construction – must become crucial for the development of the whole sector in the near

future. It will influence thinking as well as behaviour of all entrepreneurial bodies. It may be found in various prognoses and analyses more and more often; in its form and meaning, it is related to a more general concept, sustainable development. If the meaning and goal of sustainable development are relatively clear, sustainable construction has not become generally known.

In 2007, European Union countries signed an agreement on opening a number of programmes that are binding and require from member states fulfilment of determined limits and values in specified terms by 2020 and 2050.

The urgency of tasks of sustainable development made EU authorities work out common strategies of research for the European construction industry till 2030 orientating EU countries toward preparation and achievement of the goals set and agreed upon during adoption of the Lisbon Treaty. Measures to save energy, reduce emissions of harmful gases and replace classical energy sources with renewable ones are decisive. This target may be achieved, viewing the scope of the existing construction funds, in new construction, and especially in reconstruction and renovation of these funds; in particular, it applies to buildings, which consume up to 40 % of all produced power and are responsible for approximately 36 % of emissions of greenhouse gases. The strategy is binding for member states and requires fulfilment of the specified limits and values. Therefore, it is also obligatory for the Czech Republic.

Since mere specification of the limits is not a sufficient measure to safeguard savings, governments of a number of European countries turned to major investments and related motivation in this sphere, as well as to efficient international cooperation. Most countries with developed construction industry (Great Britain, France, Germany, Sweden and others) opened either government or sector programmes for sustainable construction. Their implementation should secure fulfilment of the stated goals, including specific term measures and the method of their financing and check. Government measures ensue from the knowledge that such measures which have entrepreneurial nature, i.e. those that are financially beneficial for all parties, are the most effective. It implies the emphasis on priority usage of forms of economic stimulation. Thus, interest and the needed volume of investments are gained from both entrepreneurs and households.

Timely, financially and professionally demanding information provision is an inseparable part of the preparation and implementation of the entire process. It has been proven by several workshops, seminars and information campaigns held for the professional public and building contracting firms. Also newspapers, television and radio, and even specialized programmes of major public media continually inform the public about the problems, news, and successful solution of partial questions of sustainable construction with examples of constructions and products, but also construction or rehabilitation of the whole town quarters, which are aimed to provide information to a wide public and gain support of the existing as well as future users of constructions for sustainable construction. Beside the needed and important awareness, also creation of favourable impression of building is a significant product. Such a synergic effect would continually contribute to the image of the Czech construction industry, currently presented by the media rather negatively.

The European Parliament in Strasbourg adopted a Resolution on the Revision of the Action Plan for Energy Intensity at its session held on December 15 of last year.

As mere setting of limits is not a sufficient measure to guarantee savings, governments of numerous European countries turned to vast investments in past years, and motivation in this field, as well as effective international cooperation. Most countries with advanced building industry (Great Britain, France, Germany, Sweden and others) announced governmental or sectional programmes for sustainable construction whose implementation should secure achievement of the set targets which include quite specific timed measures as well as the method of their funding and checking. Governmental measures ensue from the knowledge that such measures are the most effective whose nature is entrepreneurial, that is such procedures that are financially beneficial for all those concerned. It means emphasis on the exploitation of forms of economic stimulation. Thus, interest will be aroused and the necessary volume of investments from entrepreneurs and households will be gained.

Timely, both financially and professionally demanding information background is an inseparable part of the preparation and completion of the entire process. Tens of workshops, seminars and information campaigns organized for the professional community and building contractors testify to that. Also daily press and television or radio broadcasting and even specialized programmes of the main public media continuously inform the public about problems, news, and successful solution of partial problems of sustainable construction; they give examples of constructions and products, rehabilitation of entire town neighbourhoods aimed to provide information to the wide public and gain support of existing as well as future users of constructions for sustainable building. In addition to the necessary and important awareness, also creation of a favourable impression of the building industry is a major product. Such a synergic effect would constantly contribute to the construction industry negatively presented by the media at present.

The European Parliament in Strasbourg adopted a Resolution on the Revision of the Action Plan for Energy Intensity at its session on December 15, 2010. It sets actions that should be taken by executive bodies of the EU and national governments in the sphere of sustainable construction in the near future in the following chapters: Compliance with the Current Legal Regulations, Energy Infrastructure, Development of Towns and Buildings, Information and Communication Technologies, Transport, Incentives, and Financing. The decision on which an institution or body will fulfil this task is impatiently anticipated.

Development, discussion, approval and implementation of governmental programmes represent tremendous effort and close cooperation of numerous bodies of state administration, local authorities, experts in SIA – Council of Building (ČKAIT - Czech Chamber of Authorized Engineers and Technicians in Construction, ČSSI – Czech Association of Civil Engineers, ČKA – Czech Chamber of Architects, SPS - Association of Building Entrepreneurs, Association of Consulting Engineers, and others), together with developers, major producers of building materials and products for constructions, representatives of towns and villages, architectural and design studios, and other partners in construction.

The organizational structure of the Ministry of Industry and Trade did not have any division for the building industry, though this ministry is the only governmental body responsible for the construction industry and building materials production in accordance with the effective Competence Act. None of its divisions has needed information and, therefore, cannot provide it and bear responsibility for an adverse state of affairs in this field. What follows is total unawareness of the main goals and trends of European civil engineering and related disciplines, a constantly decreasing scope of research capacity in civil engineering, as well as a lack of financial means for securing the work by external capacities. Insufficient coordination of activities of multiple sections participating in construction, and the employment of specialized and non-governmental organizations in the section are another consequence. The Czech Republic is behind advanced countries in the area of sustainable construction by several years and the urgency of this issue has not been understood fully by competent authorities. Consequences for future competitiveness of the branch are not difficult to predict.

Information on sustainable construction is not provided to Czech sectional organizations by the ministry, but by colleagues from other countries during talks between non-governmental organizations (FIEC) and personal talks with staffs of foreign ministries within the scope of which civil engineering branch falls.

Information on the existence of programmes on sustainable construction initiated and financed by governmental bodies of due EU countries was passed to the Czech civil engineering community by representatives of non-governmental organizations active in civil engineering, particularly the Association of Building Entrepreneurs. Leading French experts presented information about French programmes upon request of the Association of Building Entrepreneurs. This issue was the main topic of the French Day at the Building Fair in Brno in 2008 to which representatives of Czech central and regional authorities were invited. The seminar was attended by a number of specialists from the practice, science and research, regional authorities and several ministries (except representatives of the Ministry of Industry and Trade) and has been, for most participants, the only source of relevant information.

The Czech Republic has no document on sustainable construction though the Association of Building Entrepreneurs has been negotiating its necessity with due sections for two years. The document should set goals, forms and the extent of the state aid, and concert efforts of state and regional authorities, entrepreneurial circles, but also scientific and research institutions, universities and training centres to make information accessible to the wide public.

The government of the Czech Republic adopted an update of the Strategy of Sustainable Development called the Strategic Framework of Sustainable Development in January 2010. Among others, also the Association of Building Entrepreneurs expressed their comments during the preparation of the document. They concretized and set tasks for due responsible sections making use of the knowledge of foreign documents and their several years' advance.

Czech economy will – like those of other EU countries – undergo principal structural changes with significant consequences for the construction industry in the near future. The Association of Building Entrepreneurs devoted one chapter in their publication Development of the Building Industry till 2012 to long-term vision of the construction industry and suggestions for its development in the Czech Republic after the end of the economic crisis.

Given the changes in the structure of demand, new progressive materials and building elements, supported by the exploitation of modern technologies, will win recognition on a massive scale. Building production will become more effective and managerial approaches will change in direction to the concept of "lean construction".

Vast investments will be aimed to save energy and other natural resources, to erect capacities connected with sustainable sources, to return to atomic energy, to build boat transport routes by connecting the Danube, Odra and Elbe and limit transport of the goods and persons, to move road transport to the railway, to restore the water regime making use of former natural techniques of regulation, to build intelligent networks of power transmission systems, to rehabilitate the housing fund on a large scale, and to recycle materials to a higher degree. Viewing the systemic perspective, consistent measures will have to be adopted to increase the self-reliance of smaller units and, at the same time, integration processes will have to continue at the level where such processes are desirable or even vital.

Current regional and urbanistic concepts will be reassessed in order to reduce the volume, distances and power intensity of transport of the goods and persons substantially, to cut consumption of raw materials and energy, to extend durability of products and constructions considerably, to prevent the origination of faults and breakdowns, and to limit the effect of unpredictable phenomena on economic and civil life of inhabitants. Europe offers numerous examples in various branches, often using different solutions of the same matter given different conditions of the place. The need for an individual approach in the region or branch ensues from that.

Most works connected with the implementation of the changes will require better and better qualified workforce. The construction industry feels shortage of qualified workforce – in the order of tens of thousands of workers in individual countries, and several hundreds of thousands of persons in total. Provided that a sufficient number of young workers are not accepted for apprenticeship in time, building firms will not be prepared to take orders as customers' conditions for higher quality constructions from more valuable and thus more expensive materials and components will continue to tighten.

Building entrepreneurs see sustainable construction as a new framework of civilization development which may be sustainable only if it satisfies the needs of the current generation without risking the potential to fulfil the needs of future generations.

Two aspects are vital for construction firms: environmental limits, and economic and social limits resulting from increasing competition pressures. Managers are beginning to understand that "green initiatives" may bring them competitive advantage. It will be a win when these initiatives will really bring them the advantage because there are still very few enlightened investors. Their priority is above all the acquisition cost rather than finding improved solutions of constructions which will secure economic profitability, will be beneficial for the society and friendly to the living environment.

Philosophy of the development of firms within the concept of sustainable development must be directed toward clients and partners in growing relationships based on listening to each other, trust and transparentness. Firms should apply a reliable approach to their own staff as concerns safety, health and knowledge development. Also, they should be forthcoming to regions, participate in economic and social life in their place of business. Viewing support of the living environment and innovations, they should support ecological solutions in designing constructions, and reduce environmental impacts of construction sites. It means environmentally friendly construction technology as well as construction equipment operated as a "green building".

Sustainable construction should also be perceived as a base of stability of national economy. Vision of future development of the state, which the Czech Republic has lacked for a long time, should be in the first place. The vision should show what income the country will generate from and what the added value, which the country can and want to offer, will be like. It must be followed by a partial concept and decisions on what investments are necessary and needed in order to achieve the income, when the state can afford them and how it will finance them. Providing that the investments' effects are clearly counted, even their debt financing is possible. The state must be aware of its exclusive position as the greatest and strongest investor and customer for the construction industry and its economic significance. It should build its investment concept as anticyclic rather than procyclic.

The future of the construction industry depends not only on the economic development, but also on whether the government will consider public investments as an effective incremental and anticyclic tool. Ensuring continuity is key as fluctuations in demand lead to the creation of excess capacities or, vice versa, to their shortage. These are personnel capacities, as well as technical equipment.
The state as the greatest investor of construction contracts plays an irreplaceable role in creating a stabilizing effect. It must plan in the long run in order to stabilize demand at a sustainable level. At the same time, it should not neglect a positive and also negative effect of the high multiplier effect of the construction industry. From this important point of view, sustainable construction means return to proportionality.
At the beginning of my speech, I said the Czech Republic lags behind advanced countries by several years in sustainable building. What should be done to catch up on this obvious delay at least partially?
First of all, the government should familiarize themselves with the real state of affairs, become aware of the necessity of change of routing and progress development, and understand that the Czech Republic lags behind the world.
Both the professional and the general public should be informed about the state of the Czech Republic in comparison with common EU requirements adopted by the Czech Republic, the state of affairs in advanced countries, and realistic needs of the national economy and ecology in years to come.
The programme of sustainable construction should be worked out and announced, including goals, means and ways leading to their achievement. (It should be done in cooperation with non-governmental organizations, universities, researchers involved in sustainable construction, and others – especially town planners, architects, regional authorities, producers and construction firms.)
The public should be informed about the methods which the government in cooperation with non-governmental organizations want to apply for reaching the targets (not mottos and other meaningless documents, but concrete measures with consequences for the entrepreneurial sphere, households, villages, producers, consumers, etc.).
The government should, like governments in advanced countries for many years, raise information awareness about the meaning of the programmes, their fulfilment, and consequences in the national, as well as international context.
In my personal opinion, as foreign experience suggests, without an immediate impulse of the Czech government that would announce, coordinate and control, with the help of substantial financial support, the programme of sustainable construction, partial measures cannot safeguard either the necessary cooperation of those who should take part, or the desirable outcomes.
The Association of Building Entrepreneurs, aware of the importance of sustainable construction, contributes to the enforcement of its principles. A year ago, the initiative of the Centre of Sustainable Construction in Brno was launched. It became a part of the National Construction Centre of the Association of Building Entrepreneurs.

I believe that today's conference will contribute to it in a substantial manner.

Sustainable Construction

I. Vaníček
Czech Technical University in Prague, Czech Republic

RESUME

Presented report is written in the form of the State of the Art Report as is giving general overview of problems falling under the term of Sustainable Construction. Report comes out from the author own experience obtained from directing the research project of the same name supported by Ministry of Education of the Czech Republic. Report also shows how wide problems are covered by this term and how much the solution of this problem at present time and also in the future can help for the fulfilment of the basic principles of Sustainable Development in Civil and Building Engineering.

Four main areas, which were solved with the help of 40 research workers from 20 different departments of the Faculty of Civil Engineering of the Czech Technical University in Prague, are:

- Construction on brownfields;
- Sustainable construction of buildings;
- Waste utilization, recycled materials in the building industry;
- Natural hazards (calamities, accidents) - an optimisation of protection, interaction with structures.

For individual areas the author is going into more details only where he is directly involved. In other parts the basic principles are defined with respect to the fact that in the frame of the research outputs another 4 volumes for the individual areas are published describing in more details the typical problems there. Persons interested in solved area can find there more details which can help them for better orientation.

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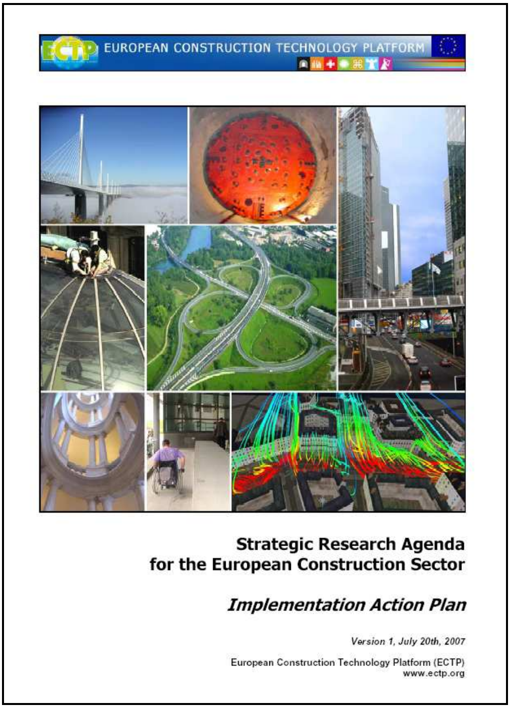
INTRODUCTION

From the international conference „Environmental Summit" on highest level in Rio de Janeiro 1992, where the conception of sustainable development was accepted and which in principle is saying that we are for global development but not at the expense of the unsustainable exploitation of natural resources, energy, agricultural land, environment in general – is this conception gradually developed in various areas of the human activities. However already in 1987 Mrs Gro Harlem Bruntland – the Norwegian Prime Minister - presented even shorter definition of sustainable development: *"Development which responds to the needs of the present without compromising the capacity of future generations to respond to their needs"*.

Over time this principle was also elaborated for the construction sector, eg. with the help of the following documents:

- UNO Agenda 21 on Sustainable Construction;
- ECTP 07/07 (European Construction Technology Platform), respectively HLG ECTP (High Level Group): Vision for 2030 "Challenging and Changing Europe's Build Environment
- Europe 2020 Strategy
    - Sustainable cities
        - energy oriented,
        - will encompass EEB (European Environmental Bureau)



At the Faculty of Civil Engineering of the Czech Technical University in Prague this approach was accepted at the beginning of nineties when emphasis on environmental problems was significantly reinforced. Later on the author directed research project „Environmental Aspects in Civil Engineering“(1998-2004), which has been given an excellent evaluation by the Ministry of Education. This project has paid a special attention to protective barriers – thermal and noise insulating, or anti-radon for housing development, respectively, or more precisely, to the barriers on the base of clay minerals used against the spreading of contamination from various landfills, waste dumps, sedimentations basins, disposal sites, including high level radioactive waste materials. The common point of view for engineering structure has been the process EIA - an assessment of the impact of constructions on the environment.

New research project “Sustainable Construction” started in 2005 and will terminate at the end of 2011. The linking aim of the newly proposed research plan is getting the knowledge of the basis and nature of observed phenomena, the explanation of their causes and possible effects for the consequent providing the economically competitive construction with the higher utility value and at the same time with the lower energy demands, the lower raw material inputs and lower need of new plots of land when the risk of the danger for human health and life during natural disasters, accidents and unwanted events is reduced.

It is responsive to the area where the civil engineer’s task is to give not only the perfect technical solution, defined also for non-standard conditions, but there is a new dimension connected with ecological, sociological, architectural and of course, economic demands. In this respect, there are tasks of the top priority the solution of which will provide the building industry with conditions generally understood as „Sustainable development“. It is necessary to carry out the really profound analysis allowing the future project aimed at its completion.

As it is not possible to cover all aspects which can be included under this subject the object of the research plan was defined by the following topics (WP´s) and which will be described in this paper in more details:

- Construction on brownfields (WP 1) - the aim is to define the conditions leading to the preferable construction on the former underused building sites, instead of the construction on the „greenfields“. The reason is that at the present time pace of assignment of greenfields for new constructions is not acceptable from the sustainable development point of view.
- Sustainable construction of buildings (WP 2) - the aim is to find a balanced relation between the building activities and constructions with the interior environment of good quality on the one hand and the environmental burden on the other hand in the whole life cycle of constructions - especially with the respect to building materials and a low energy consumption including renewable resources.
- Waste utilization, recycled materials in the building industry (WP 3) - the aim is to define the conditions allowing reducing production of waste, to develop recycling of waste, particularly the building waste materials and their reuse in new construction of buildings. This point of view is taken into account during the designing of new constructions and assessment of their life cycle.
- Natural hazards (calamities, accidents) - an optimisation of protection, interaction with structures (WP 4) - the aim is to reduce the negative impact of

these phenomena both on lives of inhabitants and property damages. A risk analysis, a probability method, an optimisation of protection, a safe technical solution of building structures under the extreme conditions are therefore applied to be able to solve this very sensitive problem.

1 CONSTRUCTION ON BROWNFIELDS

The aim is to define the conditions leading to the preferable construction on the former underused building sites – Fig. 1.3 and 1.4, instead of the construction on the „greenfields“ – Fig. 1.1 and 1.2. The reason is that at the present time pace of assignment of greenfields for new constructions is not acceptable from the sustainable development point of view.

Figure 1.1: Construction on greenfields

Figure 1.2: Construction on greenfields

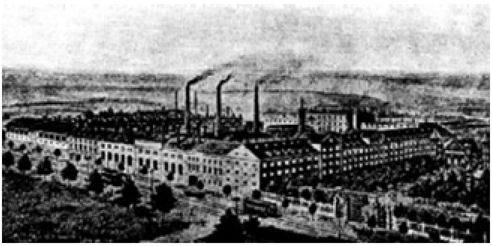


Figure 1.3: Construction on Brownfields


Figure 1.4: Construction on Brownfields

Firstly it is necessary to say that the solution of the construction on brownfields requires complex solution with multidisciplinary approach.

In spite of the difficulties how to calculate the area of greenfields used per day for the new construction in individual countries, some value are alerting, e.g. in Germany the estimation is around 1 200 000 m2 per day. Therefore in some countries the governmental policy declares the aims for the future and at the same time defines legal regulations how these aims can be reached, how more brownfields have to be used for new construction. In principle it is the reaction to the fact that especially in cities many previous activities are closed as, mining activities together with concentrator factories, heavy industry as metallurgy, light industry as textile industry, together with dwellings not fulfilling up to date demands.

But on the other hand there are new demands for different offices, banks, shopping centres, garages together with new demands on apartment blocks.

1.1 *Brownfields definition*

There are different definitions of brownfields, e.g. Kuráž, 2005, however hereafter the definition of CABERNET European network will be presented. The EC funded "Concerted Action on Brownfields and Economic Regeneration Network (see www.CABERNET.org.uk) was established in January 2002 to enhance the regeneration of brownfield sites by developing an intellectual framework to structure ideas and stimulate new solutions, e.g. Nathanail et al., 2003. The following definition of brownfields is used there:

- Have been affected by former uses of the site and surrounding land;
- Are derelict or underused;
- Are mainly in fully or partly developed urban areas;
- Require intervention to bring them back to beneficial use;
- May have real or perceived contamination problems.

According to this definition brownfields with contamination but also without it can be recognized. Therefore one of the first steps during the phase of brownfields investigation is connected with adjustment of the risk. However the ground cannot be affected only by chemical impact, but also by physical or biological impacts, when the physical impact is mostly connected with lower porosity, with the risk of higher total and differential settlement, and biological impact is very often connected with the presence of methane. In all cases a special care to foundation has to be devoted.

1.2 *Brownfields classification*

The brownfields classification strongly depends on the stand-point from which brownfields are differentiated, Vaníček, 2006. According to different stand-points we can differentiate between:

- Brownfields where the subsoil is contaminated or not – differences in the degree of contamination;
- Brownfields inside of cities – urban brownfields and brownfields out of towns, above all lands connected with previous mining activity and concentrator factories – differences in location –Fig. 1.5 – 1.7;
- Small and large brownfields – differences in scale

In some cases special brownfields can be defined as well, e.g. military brownfields or railway brownfields, e.g. Vodný, 2011, even sportive brownfields, e.g. Kramářová, 2011.

Figure 1.5: Brownfields – differences in location – urban.


Figure 1.6: Brownfields – differences in location - country side


Figure 1.7: Brownfields – differences in location – mining.

However given practical implementation the financial aspect is extremely important, therefore from the financial perspective we can differentiate between:

- Brownfields which are attractive for private investors – above all urban brownfields in large cities as capitals;
- Brownfields where the attractiveness of land can balance the higher cost of redevelopment;
- Brownfields where private investors are attracted by some investment stimulus from the government or municipalities, or where some sort of public-private-partnership is established;
- Brownfields redevelopment (first of all contamination remediation) of which should be taken care and financially supported by the government or municipalities.

From this perspective it is obvious that the market cannot solve all cases. In fact there are three aspects, the financial one, the potential environmental risk and the time factor. The financial one compares the sum of money which is spent for purchase of the brownfields land plus money for preparation of brownfields for new construction with the price of greenfields. The potential environmental risk is connected with uncertainties of the remediation process, whether the recommended process of remediation will reach the demanded values, whether there is the risk of supplemental increase of chemical contamination or whether the acceptable boundaries will not be decreased by additional law. However the time factor is also important because some investors prefer speed, to start with construction as soon as possible, e.g. with construction of different supermarkets etc. Therefore they are not trying to go with new construction on brownfields because there is always some delay. Some of these aspects will be shown in next chapter, where individual steps of the brownfields redevelopment process are discussed.

1.3 *Individual steps of the brownfields redevelopment*

Very often the whole process of the brownfields redevelopment can be divided into the following individual steps, e.g. Vaníček and Valenta (2009), Fig. 1.8:

- site location identification,
- first phase of investigation,
- preliminary economic analysis,
- second phase of investigation – detailed site analysis
- project of site development and methods of financing – feasibility study
- project and completion of site remediation
- project and completion of construction of new development (including foundation engineering, reuse of old foundations).

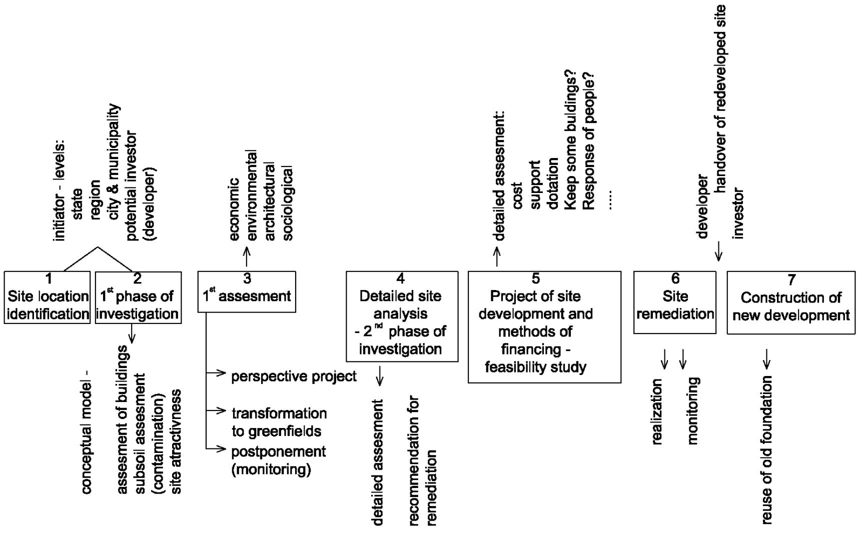


Figure 1.8: Basic steps of Brownfield redevelopment

From these basic 7 steps, it is obvious that environmental geotechnics is strongly involved in the whole process. But typical for geotechnical engineers are four parts – 1st phase of investigation, 2nd phase of investigation – detailed site analysis, project and completion of site remediation and the problem of foundation engineering, respectively reuse of old foundations. These parts will be discussed further in more detail, Vaníček, 2010.

The first two steps are labelled as the first phase which can be also called the desk study, which is only supplemented by visual inspection. So this first phase mostly uses existing materials, where the study of archive materials and different maps composes the most important part of this phase, Vaníček, 2005, Valenta, 2005.

Preliminary economic analysis has a key role in defining the suitability of the site for new construction, how this site can attract a new investor, especially after the comparison of financial inputs for redevelopment and the economic return. This preliminary economic analysis is supported by architectural study (which can for example define if some of the old buildings should be protected), and social study – how the redevelopment can improve the style and quality of life in the affected area.

The 2nd phase of the investigation encompasses site investigation, usually starting with borings, field tests, collection of samples and laboratory tests. Classical geotechnical data are useful from the foundation design perspective, geoenvironmental data from the view of site contamination.

Feasibility study evaluates the workability from the financial point of view and defines the financial plan for remediation and completion of construction. The project and completion of site remediation can be very expensive if the degree of contamination is a high one, and includes the whole process of remediation (starting from the evaluation of contaminant spreading as a function of time and position, comparison of the obtained data with limits defined by administrative body, the selection of the most appropriate method, phase of completion and ending with monitoring, which have to prove that the proposed level of clean up was reached), the impact on the existing community and the final report for the administrative body, Vaníček, I. (2002b).

1.4 *Brownfields strategy*

Probably the greatest problem is now connected with existing preference of the construction on greenfields. Mostly due to reasons mentioned above. However this fact leads to so called “Urban sprawling” and is schematically shown on Fig. 1.9.

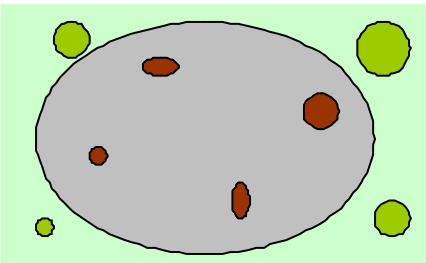


Figure 1.9: Sketch of the problem of “Urban sprawling”

Broadly speaking we can stress the following positives of the construction on Brownfields:

- existing infrastructure,
- remediation of wider areas

Similarly we can stress the following negatives of construction on Greenfields:

- demands on new infrastructure;
- demands on transportation to city

To change this tendency there is need for governmental support, which can defined either Strategy of the regional development or Politics of the territorial development. UK was one of the first countries which declare such strategy - 60% of new construction should be situated on brownfields. Similarly Germany declares to decrease daily consumption of 120 ha of greenfields to 20 ha for year 2020. For the Czech Republic estimated consumption of greenfields per day is roughly 18 ha, therefore also government declare National strategy for brownfields redevelopment, Mansfeldová, 2007.

Individual national strategies are very often based on up to date experiences. There it is necessary to distinguished between extremely large projects, as is for example the case for London Docklands, which is now much more widened as sports facilities for Olympic Games in London 2012 will utilize mostly the similar brownfields. Therefore this case will be described briefly. However on the other hand most of the brownfields are smaller one and are not as attractive as large urban brownfields. Therefore the approach how to propagate this smaller one will be described also as is part of the National strategy in CR.

1.5 *London Dockland remediation*

The London Docklands Development Corporation was set up by an Act of Parliament in 1981 as an urban development corporation. Its objective was to secure the regeneration of the London Docklands Urban Development Area comprising 8.5 sq miles of East London just 3 miles from one of the largest and influential financial centres of the world. This was a Government led response to a huge decline in the economy of the area brought about by the progressive closure of the docks from the 1960´s which led to the loss of 12, 000 jobs. A certain advantage there was the fact that a high proportion of the land at that time was held by public bodies, Berry, 2003.

Remediation of the site was a very difficult task as the ground was contaminated physically and chemically. Physical contamination was defined there as contamination which causes an adverse variation to the mechanical and physical characteristics of the subsoil to the extent that the engineering design must take due regard of it. Chemical contamination was treated either by removal and replacement of contaminated soil or by direct treatment in the place.

By 1998 when the project ended 85, 000 permanent new jobs had been created in Dockland, and thousands more were created during its construction. The locality completely changed its character and now can be characterized as a part of the modern, environment friendly city, Fig. 1.10.

a)

b)

Figure 1.10: London Dockland – a) general view 1983 – according to Berry, b) present view – the O2 and Canary Wharf from the Royal Victoria Dock - Wikipedia

1.6 *Database of practical examples*

In the Czech Republic there are different databases of brownfields, e.g. Vaníček and Jirásko, 2007. The main brownfields connected with large industrial sites are part of the database prepared by the CzechInvest for more sensitive cases with the support from EU. This database is used mostly for strategy of brownfields remediation in the Czech Republic.

On the other side the smaller ones are much more under the interest of the Ministry of Local Development. With financial support of this ministry the database of existing cases of revitalized brownfields, preferably for smaller towns, was prepared at the Czech Technical University Up to now this database contains roughly 60 examples of brownfields, which were already revitalized in different parts of the Czech Republic.

the first information about this project and they were introduced with web pages where these first sixty examples were presented.

The results of database are open to the public on the web http://dotaznik.brownfieldsinfo.cz and anybody can display the collected data about concrete sites. For adding of new brownfields the registration is required.

The database includes the basic information about brownfields such as location, area, price, information about previous use, about contamination and realized treatment. Further it is possible to obtain the data about new project and new use of property, about time schedule, financial aspects, etc. It is also possible to show map and photos before and after redevelopment and so learn as much as possible from the concrete case.

The municipality representatives were informed about access to the database and they were asked to put their own experience into the database.

1.7 *Basic steps of the Brownfields redevelopment*

For practical evaluation of all problems which can be expected it is recommended to follow the procedure which was presented on. 0.

First two steps as is site identification and 1st phase of investigation have to start by someone, e.g. by state, local government, municipality, investor either owner of the land or external investor or developer. For all of them the result of these two basic steps is very important as the basic material for 1st assessment of the locality. So these first two steps are described in more details.

1.7.1 *First phase of investigation*

Site identification is mostly connected with identification in the real estate register, where the first information about the site area, the owner, and some other conditions can be obtained. The type of owner can have some influence on different grants, which can be obtained from different agencies. Supplemented materials are – prices for parcels in a wider area, potential interest, and advertising, all of them can help to define the potential attractiveness of the site.

Visual inspection. The main aim of the visual inspection is to give the first information, above all about morphology in the wider area, surface water, ground water via observation of old wells, discussion with owners about quality of water, information about vegetation, inspection of existing buildings with brief evaluation of their situation, with special aspect of unusual symptoms, as colour, odour, talks with older citizens, with old employees, whereas all visual inspection will be supported by photographs, videos, etc.

Archive and up-to-date data collection. This step will help to obtain or find not only useful information about buildings, but also about the type of production, with what materials the production was connected, what sort of waste material was produced. From the archive and other historical documents some information can be obtained about potential problems or accidents in the past and from these data the probability of soil and water contamination can be judged. And finally different hydrological data can be useful as well. Nevertheless the most valuable data are obtained from Geo-environmental maps. Further main steps are defined, while details can be found e.g. in Vaníček and Valenta (2009).

- General information about buildings;
- History of the buildings utilization;
- Information from the archive and other historical documents;

- Materials from hydro meteorological institutes;
- Materials from aerial observation – military and civic photographs
- Set of different maps.

From different maps e.g. in the Czech Republic the following can be used:

- Set of Geoenvironmental maps
- City maps with surroundings, contour plans
- Land-use plans, Ortho photo maps, GIS system
- Infrastructure and underground service plans
- Maps of documentation points - Materials from Geofond – state office, where all boreholes data are collected for the whole Czech Republic as borehole geology description, geotechnical data, ground water level etc.

A very important source of information can be obtained from a set of Geoenvironmental maps in the scale 1:50 000. In the Czech Republic this set is composed of up to 17 maps, the most important are geological, hydrogeological, engineering-geology, mineral deposits, rock geochemical reactivity, soil or geophysical maps, or maps of surface water geochemistry, or geofactors of environment. Only 3 of them are shown further.

The geological map is a fundamental map, which is necessary for constitution of all other layers, Fig. 1.11. This map represents rock and soil types in the ground, their age, stratigraphy, tectonical position and so on.

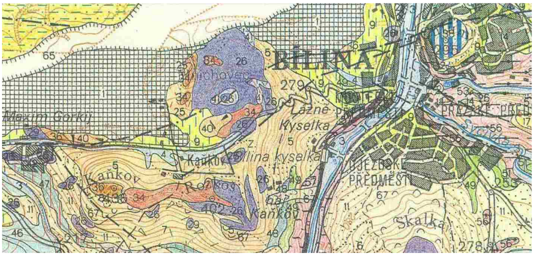


Figure 1.11: Example of the Geological map (1:50 000)

The hydrogeological map describes types of hydrogeological aquifers and their quantitative characteristics, Fig. 1.12. A colour in a map projects discharge of ground water (m^3/s). Different symbols indicate ground water quality from the serviceability perspective, ground water flow direction and important boreholes with water yield and mineralization data.

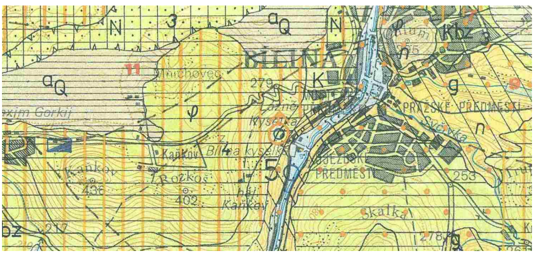


Figure 1.12: Example of the Hydrogeological map (1:50 000)

The Map of surface water geochemistry, Fig. 1.13, shows a catchment area of water streams and their pH value. On the map the water sampling place and he trace elements content (As, Pb, Be, Zn, Li) are marked. The map of water surface geochemistry displays the level of pollution of the water surface.

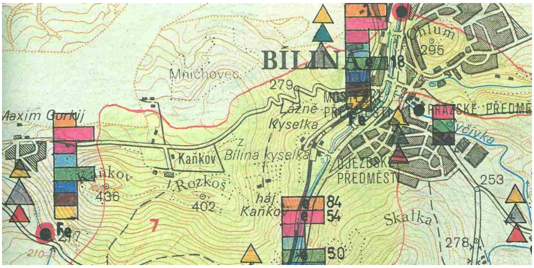


Figure 1.13: Example of the Map of surface water geochemistry (1:50 000)

For the largest cities in the Czech Republic, e.g. for the capital of Prague maps in a larger scale can be used – in the scale 1:5000, however only 4 such maps are there – geological and hydrogeological maps and maps of superficial deposits and documentation points (from Geofond).

Briefly speaking the main aim of this phase is to obtain maximum relevant information with minimum financial input. According to the author’s opinion all the obtained information is a very useful tool for the decision making process on the municipality level and should be recommended to all municipalities dealing with the problem of brownfields, because it gives a reliable answer to the following four questions:

- Potential site contamination – on the one hand the first phase of investigation collects all information, from which researchers can distinguish whether contamination occurs, at what level and at what extent. On the other one, from other information, engineers can estimate the possibility of spreading of contamination in subsoil (e.g. direction, velocity) and what impact on the surrounding it can have.
- Evaluation of the potential of the site – information which makes the best account of this fact is the site size, disposition, quality of buildings, halls, technical equipment, quality and density of engineering networks, what can be used in the future, what is recommended for demolition etc.
- Site attractiveness – in which the part of the city is situated, what is traffic accessibility, what is concurrency in near surroundings. What are restrictions (e.g. from the owner ´s point of view), whether there are some burdens. Comparison with similar localities or similar projects, why they were successful or only partly successful and the reason of this fact. What is the position of citizens to the remediation process, what profit citizens and local authority can obtain (higher prices of the surrounding areas, lower unemployment etc.).
- Recommendation for the second phase of investigation.

1.7.2 *Second phase of investigation*

This phase is predominantly orientated to the application of direct investigation methods with the help of which findings from the first phase can be verified and supplemented.

The classical approach is based on the drilling, collection of samples (water, soil, air) and geotechnical and geochemical analysis in the laboratory. This classical approach has many advantages but also disadvantages giving information only for a selected point from which samples were extracted and also that there is a direct exposition of contaminated soil with a drilling crew and the need to safely deposit unused material on landfills.

Geophysical methods are based on the changes of geophysical characteristics. Predominantly these methods are cheap and operative. Most commonly they are orientated to obtaining a continuous picture between boreholes, points of sample collection, or the picture of the cross section of the observed subsoil. They are able to recognize the boundary between subsoil with different physical (moisture content, temperature), mechanical (density, stiffness) properties as well with different chemical properties (pH, electrical conductivity, radioactivity etc.). However the interpretations of the measured data require good experience.

Hydrogeological investigative boreholes are very useful for non problematic subsoil, as open piezometers can be used for definition of pore pressure and sampling of water, respectively for pumping tests for permeability determination. However for laminated subsoil, where only one layer is contaminated, a borehole can constitute potential danger of contamination spreading as well as interconnection of layers with different pore pressures.

Therefore during the last period different penetration methods are preferred, specially cone penetration tests - CPT. Lunne, Robertson and Powell (1997) give an overview of these methods where for the classical geotechnical investigation cone resistance, skin friction, and pore pressures are determined (CPTu test). Generally CPT tests are used for the following information:

- Nature and sequence of subsoil layers (geological data);
- Ground water information (hydrogeological data);
- Physical and mechanical properties of individual layers (geotechnical data)

For contaminated subsoil penetrometers with additional sensors were developed, enabling to measure temperature, electrical resistivity or conductivity, pH, redox potential, radioactivity, etc. Two examples of such penetrometers are in 04.

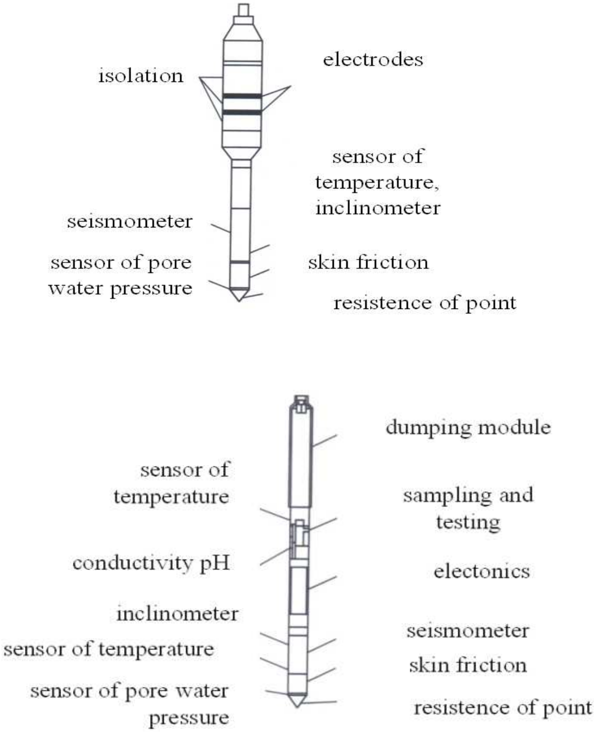


Figure 1.14: Cone penetrometers with additional sensors

Testing the samples from the same points in different time, researchers can obtain the degree of contamination as a function of the position and time. So engineers can get the first information about contaminant spreading in time. These results can be checked, verified and prolonged for future time by numerical modelling, after determination of input data into a numerical model of contaminant transport equation, taking into account not only advection but also diffusion, dispersion, and sorption.

The basic equation for a 2 D problem of contamination spreading in an earth domain may be written in the form (Eq. 1):

$$n\frac{\partial c}{\partial t} = n \cdot D_x \frac{\partial^2 c}{\partial x^2} + n \cdot D_z \frac{\partial^2 c}{\partial z^2} - n \cdot v_x \frac{\partial c}{\partial x}$$
$$- n \cdot v_z \frac{\partial c}{\partial z} - \rho_d \cdot K \frac{\partial c}{\partial t}$$

which expresses a change in the concentration c of a certain substance in time t in relation to the porosity n and the groundwater flow velocity v in the direction z and x. Further on:

D_z , D_x – are coefficients of hydrodynamic dispersion in directions z, x,

K – distribution coefficient

This equation incorporates contaminant spreading through the following processes:

- Advection – contaminant movement with flowing water, the decisive factor being the water velocity v
- Diffusion – expressing contaminant movement from a point of a higher chemical concentration to points with a lower concentration, the decisive factor being the effective diffusion coefficient D_e
- Dispersion – which includes “mixing“ and dispersion due to the non-homogeneity of the aquifer, the decisive factor being the coefficient of mechanical dispersion D_m
- Sorption – i.e. mechanisms which remove contaminants from the solution, the decisive factor being the distribution coefficient K.

The obtained data of contaminant concentration as a function of position and time are compared with allowable limits defined by the national ministry of environment or by the national environmental protection agency. As a result of this comparison the potential risk of the observed locality and the need of remediation action are defined.

The detailed assessment of the brownfields site, based on the result of the second phase of investigation, is also connected with recommendation for site remediation, either from the chemical, and/or physical or biological views.

1.7.3 *Brownfield site remediation*

The properties of the brownfields ground is usually affected by previous man made activity. These changes have character of physical, chemical or biological change. Owing to biological degradation some problems with gas (mostly with methane) are expected. However in most cases the subsoil remediation is connected with

- Physical improvement of the subsoil quality, with porosity decrease;
- Chemical improvement.

1.7.3.1 Physical improvement

As the depth of the affected subsoil is usually deeper than the depth for which classical compaction rollers can be used it is necessary to apply other methods. The dynamic consolidation method was for example used for the subsoil improvement of old toxic landfill in Neratovice, where on the compacted material a new landfill was constructed, e.g. Vaníček et al., 2003. The dynamic consolidation method was chosen there not only in order to improve the quality of the subsoil material to a much greater depth than using other methods, but also because the so called observation method can be used for a step by step improvement by the monitored response of the subsoil. For the given case the pounder weighing 15 tonnes falling from the height of 20 m was used, see 0. The effectiveness of this method was demonstrated not only by a considerable immediate compression of the surface – 0.567 m on average – but also with the consolidation reaching a considerable depth – 10 m. This deep improvement was controlled by CPT tests before and after dynamic consolidation was applied.

Figure 1.15: Compaction of deposited waste by dynamic consolidation

In the north part of Bohemia, where there are many inner spoil heaps composed of un-compacted clay clods, a new method called “clay piles” was successfully applied.

A pre-driven profile is backfilled by clay of similar properties as is the surrounding material and subsequently compacted there, see 0

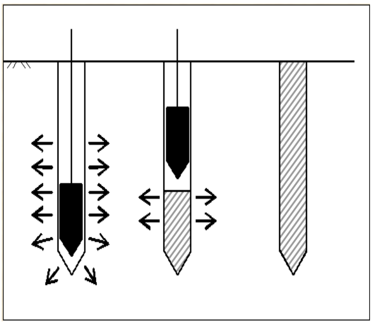


Figure 1.16: Un-compacted clay clods and ground improvement by “clay” piles

1.7.3.2 Chemical improvement

Before the final decision about the remediation process all information about subsoil, the type of contaminant and interaction between them have to be well known and evaluated.

From the perspective of subsoil we have to distinguish between homogeneous and anisotropic subsoil, subsoil with high or low permeability, respectively between subsoil which is fully saturated or unsaturated etc.

From the perspective of the contaminant type, we have to distinguish between:

Organic and inorganic contaminants, (hydrocarbon x metals, cyanides and ammoniac)

Contaminants easily and poorly soluble, when poorly soluble are labelled as "nonaqueous phase liquids" – NAPL

Contaminants lighter-than-water (LNAPL) and contaminants denser than water (DNAPL) .

And finally from the interaction perspective we have to distinguish, mainly for hydrocarbons, as these contaminants can exist in four different forms, as:

- Vapour;
- Isolated mobile liquid phase – NAPL;
- Adsorbed phase – on individual soil particles;
- Partly dissolved in water, soil humidity

There is a very wide range of different methods which are used for site remediation. It is not the intention of this lecture to present the overview of these methods, because they are covered elsewhere, e.g. Suthersan (1997), are summarized by US EPA or are a part of activities of ICEG – International Congresses on Environmental Geotechnics. Most of the methods utilize some geotechnical approaches, as drilling, pumping, hydraulic fracturing, and monitoring.

Nevertheless there are 3 methods preferably utilizing classical geotechnical methods as:

- Encapsulation – with the help of the underground sealing wall (Different types of cut-off walls) and the horizontal sealing system (CCL – compacted clay liner, GCL – geosynthetic clay liner, GL – geomembrane liner or composite liner), see (Fig. 1.17).
- In situ permeable reactive barrier – when with the help of vertical sealing wall the contaminant plume is directed to the permeable window – permeable reactive barrier - where contaminated water is cleaned – with the help of sorption, precipitation or degradation, Jirásko and Vaníček, 2011- see (Fig. 1.18).
- Stabilization, solidification, - these methods are based on the principle of mixing waste with a bonding agent to create a stiff matrix where the contaminant is bonded. As a bonding agent the different combinations of cement, ash, lime and slag are usually applied, see (Fig. 1.19).

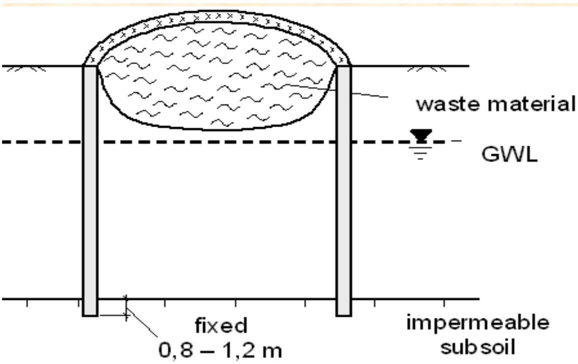


Figure. 1.17: Remediation by encapsulation

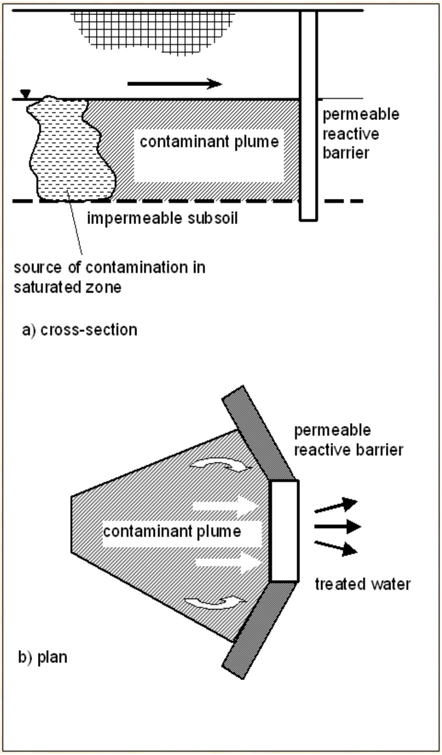


Figure 1.18: Remediation by in situ reactive barriers

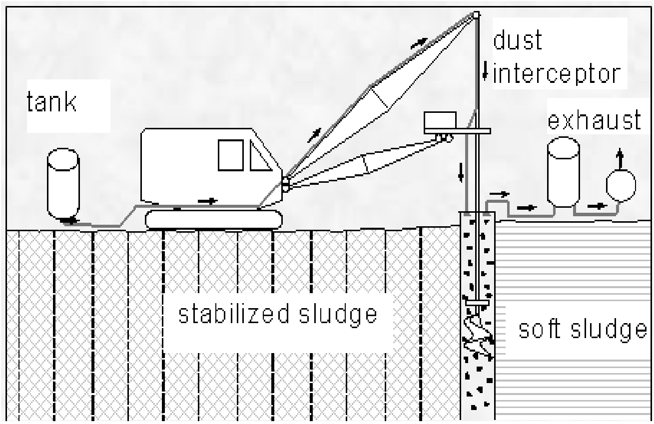


Figure 1. 19: Remediation by stabilization

1.7.4 *Foundation of new structure*

After the physical and chemical subsoil improvement there should not be great problems with the foundation of new structures, nevertheless engineers have to be very careful about contaminants residuum because some problems with concrete degradation and steel corrosion can start.

However interesting problems are on sites where old foundations exist. This case applies to centres of major cities across the World. Throughout history mankind has been content to build new buildings on the remains of the previous ones to save the time and trouble of digging new foundations. Such examples can be found for churches, e.g. in Prague the Baroque church was constructed on the gothic one. And this Gothic church was constructed roughly in the 13 century on the oldest Romanesque church from the 9 century, Fig. 1.20.

The discussion about utilization of old foundations is now typical of large cities as the average design life of office buildings is about fifty years. So it means that buildings constructed in the 1950´s- 1960´s are now often demolished and reconstructed. Many of these large modern buildings have been designed with wide column spacing necessitating the use of deep piles or piled raft foundations, as was the case e.g. for London, Chow (2003). Therefore the discussion is about three options – avoid, remove, reuse. The last option is now preferred as reuse of old foundations has many positive aspects from the environmental point of view, e.g. Butcher, Powell and Skinner (2006), as this option reduces:

- Use of natural resources;
- Total energy used;
- Potential for groundwater level changes and groundwater pollution during construction;

Figure 1.20: St. Marketa baroque church and old foundation of Romanesque church.

- Quality of waste materials produced both during demolition and construction;
- Number of vehicle and plant movements.

However before the final decision it is necessary in general to collect all possible information based on the available data and new investigation, during technical assessment to count with ground conditions, the foundations layout and dimensions, integrity and durability and with the load capacity and performance.

The final decision therefore can recommend the old foundations reuse, reuse with repairs or augmentation, or no reuse. The decision not to use the old foundations can also be affected by the investor, asking for higher utilization of underground spaces, as for example for garages.

Especially the problem of assessment of the existing pile foundation capacity is a very complicated process and is not only based on old construction records, but has to take into account also changes in the surrounding soil with time as a result of changes of stresses induced there by loading, unloading and reloading.

The above discussion in principle applies also to spread foundations, which were used for old dwellings, e.g. prefab panel buildings; for farm buildings as well as for old industrial structures. Although the price for removal is not as problematic there as for pile foundations, the version of reuse is very attractive. Here the bearing capacity for subsoil composed of clays increased with time as the result of consolidation. Also the foundation settlement induced by new loading can be rather low, as some additional structural strength had chance to develop there with time for particle arrangement given by stresses from the old foundations. The possibility of foundation strengthening is easier for spread foundations. For example a combination of old footings with micropiles can be a good solution.

Many practical examples for pile foundations are presented by Butcher, Powell and Skinner. They also discuss design of new foundations for future reuse. So it means that new foundations can have a much longer lifetime than the rest of the structure. This approach can be attractive for geological profile, where good subsoil is in a reasonable depth. The perimeter of the foundation pit can be constructed from a cut-off diaphragm wall and the contact with good subsoil uses the foundation slab. In this case some underground levels can be used and in future there is no problem to reinforce this slab directly or via additional piles below it.

For spread foundations, which were used for the old dwellings, e.g. panel buildings; for the agricultural buildings as well for the old industrial buildings the situation is similar. Although the price for removal is not as problematic there as for pile foundations, the version of reuse is very attractive. Here the bearing capacity with time for subsoil composed from clays increased with time as the result of consolidation. Also the foundation settlement induced by new loading can be rather low one, as some additional structural strength had chance to develop there with time for particle arrangement given by stresses from old foundations. The possibility of foundation strengthening is for spread foundation easier. For example combination of old footings with micropiles can be good solution.

Direction of the new research activity is therefore connected with observation of changes with time not only in subsoil surrounding existing foundations but also at the contact with this foundation. For bearing capacity and for settlement stress and strain paths are more complicated. Schematic drawing what is going for selected layer below spread foundation is shown in Fig. 1.21, Vaníček, 2010,b, and new laboratory and field investigation should to prove some expected assumptions.

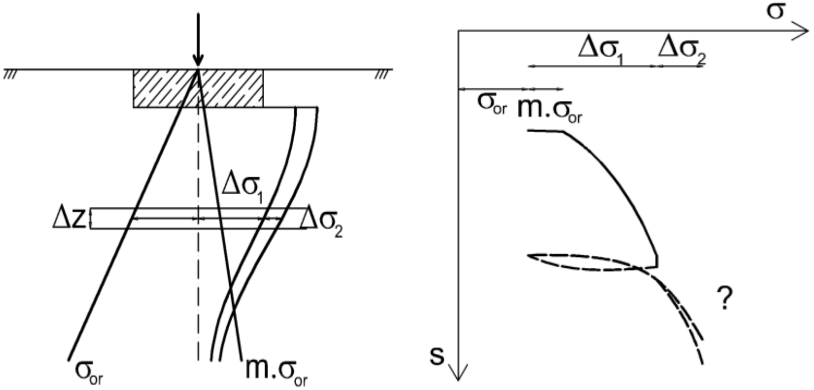


Figure 1.21: a) scheme of vertical stresses below spread foundation; b) expected settlement by additional loading $\Delta\sigma_2$.

Special problems have to be solved, when city brownfields are used and existing structures are in close vicinity, as Fig. 1.22. Interaction of new structures and older ones is very sensitive, as due to stress changes (e.g. due to excavation) also changes are induced under old foundations which lead to additional deformation. To limit this additional deformation (either vertical or horizontal) special methods of foundation engineering are applied there. Fig. 1.23 is showing different methods of old foundation underpinning.

Figure 1.22: Utilization of city brownfields – problem of interaction with existing older structures

Figure 1.23: Different methods of underpinning.

1.8 *Practical Examples*

1.8.1 *Prague – Sazka Arena*

The capital of the Czech Republic Prague is not only a historical city with unique architecture in the centre but also with many heavy-machinery industries around, not so far from the centre. The brownfield site "Green island" a part of which is Sazka Arena is situated in the northeast part of Prague. For the last century this place was used by CKD company, producing there locomotives. The main activities ended there in 1994. The fundamental conception counts with redevelopment to a central multi functional complex with a congress centre, hotels, entertainment centre, shopping and administrative centres as sport playgrounds. The locality has very good transport accessibility by the metro system and along both sides there are tram and railway tracks.

The first part of this complex Sazka Arena was opened in 2004 with the world ice-hockey championship. The site investigation started in the phase when most of the old buildings were demolished, see Fig. 1.24.

Therefore many complications were there, especially in connection with underground structures, cables, pipelines etc. This investigation proved the geological profile with the bedrock composed mainly of black clayey shale which is covered by deluvial and fluvial materials. The terrain is inclined in one direction to the brook passing through a small valley. Two water collectors are there, the first one in quaternary sediments and the second one in the bedrock, Schröfel, Chamra and Valenta, 2002.

Contamination of subsoil was mainly created by hydrocarbons (mostly oil), but only locally. It was approved that the bedrock was not affected. Since the foundation slab was situated on the top of the bedrock, the recommended solution was rather simple. All the overlying material was excavated and treated off- site. To solve the problem of ground water, drains for gravitational dewatering was proposed and bentonite mattresses applied to improve the sealing capacity of the concrete slab. Great care was devoted to the cleaning of the bedrock surface to prove a very good contact with the foundation, see Fig. 1.25.

Irregularities were fulfilled by concrete. Now the Sazka Arena is an integral part of the city, see Fig. 1.26 and the surrounding area is under the process of reconstruction as well.

Figure 1.24: Sazka Arena - Demolition of old structures

Figure 1.25: Sazka Arena - cleaning of the footing bottom

Figure 1.26: Sazka Arena – after construction

1.8.2 *Ostrava – Karolina*

Ostrava is the third largest city in the Czech Republic with 320, 000 inhabitants, situated in the northeast part of the country, close to the boundary with Poland and Slovakia. Heavy industry was typical and still is for the Ostrava region, with deep coal mines and many metallurgical factories.

The area of brownfields Karolina, covering 60 ha, lies just in the city centre, approximately 500 m from the historical main square, e.g. Fišer et al (2003). It is a unique situation, when so close to the city centre there is such a large area available. A real chance for the expansion of the city into this area started in 1988, when the industrial activities went down there and the facilities had been destroyed. But the real subsoil contamination due to nearly 150 years of different activities was a limiting aspect. The main industrial activities in this area were: Iron works, a coking plant, mining shafts, chemical plants and a power station, see Fig. 1.27.


Figure 1.27: Historical view on Karolina area

The coke production including the related chemical activities was the main reason for ground contamination. The main contaminants are tars, oils, poly-aromatic hydrocarbons, aromatic hydrocarbons, phenols, sulphide and ammonium ions as well as heavy metals.

Detailed site investigation was performed between 1992 and 1995 and after that together with foreign experts an investigation report was prepared together with a risk analysis of the ground contamination and finally a conceptual design for remediation was proposed. As the area is situated close to the river Ostravice, the geological profile contains many fluvial sediments, clays, sands, gravels, which are situated on tertiary clays (Miocene clays) which were found at the depth of 8-11 meters. However fluvial deposits were covered by made-up-ground formed mainly by concrete, steel, bricks, tars, construction demolished materials etc. The highest contamination occurred on the impermeable clay layer at the depth of some 11 m bellow the terrain. It was also clear, that this contamination would further spread along the clay bedding towards the ground water flow, it means especially towards the city centre. The main aim of the remediation process was to stop this spreading. Off-site thermal desorption was used as the main remediation method but also on-site methods as pump and treat, air venting with help of injection of steam and detergents. An international architectonic tender was opened in 2000 and a general winner was a team from Gliwice, Poland, Fig. 1.28.

Figure 1.28: Ostrava Karolina – Developer view – MULTI Development Czech Republic a.s.

The original expectation that the new construction will start immediately at the end of remediation in 2005 was not fulfilled, but at the end of 2009 the developer declared the assurance from banks to finance all the expected cost about 600 mil. EUR.

1.8.3 *Ostrava region – New Vitkovice*

Similar as Karolina is another complex in this region – Vitkovice. In 1998, after 170 years of activities, the production of raw iron, coke and agglomerates was closed there. In 2002 this part plus the deep mine Hlubina were declared by the government as the National Cultural Monument (NCM) and in 2008 as European Heritage. The engineering company VITKOVICE MACHINERY GROUP is now preparing a unique project New Vitkovice, which counts with remediation of this part. The main aim is to protect the industrial heritage for next generations, while giving this area a new, modern and valuable image, to construct new flats, administrative buildings, research and university facilities together with areas for cultural and playtime activities, Fig. 1.20.

In the frame of NCM activities three basic objects will be reconstructed and protected:

- Power station – central;
- Blast furnace
- Gas-holder

A special exposition "Universe of Technology" is proposed as a part of this new area.

Figure 1.29: New Vítkovice – general view

1.8.4 *Prague – Karlin, Rohan*

The last example represents a combination of classical brownfields with a flood prone area as during heavy floods in 2002 this area was completely flooded. The Vltava River passing through the centre of Prague had the old river-basin in this place. About a hundred years ago this river-basin was shifted about 100 m apart. The old river-basin was refilled with gravel or permeable backfill. The bedrock is composed by shale in different phases of weathering and is overlaid by alluvial deposits of different characteristics and partly by man-made deposits. In this prone flood area the old structures as stocks and small workrooms were used there in most cases.

After floods in 2002, the dike, the protection dam along river, was increased to protect the area against roughly 500 year's flood. However the protected terrain is about 3 m lower than the crest of the new dike, see the plan and cross section, Fig. 1.30.

When the developer started to think about future utilization two problems came forth. The first one was connected with the water level in the river Vltava which is higher than the surrounding terrain. It is a significant factor influencing the sensitivity of the dike subsoil to piping, a factor affecting the underground water table increase and a factor enabling the outlet of water from the nearest brook to the river Vltava. Protection gates were constructed in the place of meeting of the brook with the river Vltava together with a pumping station to pump water when the gates are closed to the main stream.

The second problem was connected with foundation of new buildings with 3 up to 8 above-ground floorings and with proposed only 1-2 underground floorings, Fig. 1.31. In this case the ground water table under general conditions is lower than the foundation slab. When the ground water table is higher during foundation construction, a version with artificial flooding of the foundation pit was proposed. Also for the finished structure the underground floors will be flooded when the water table will be roughly 1-2 m below the terrain.

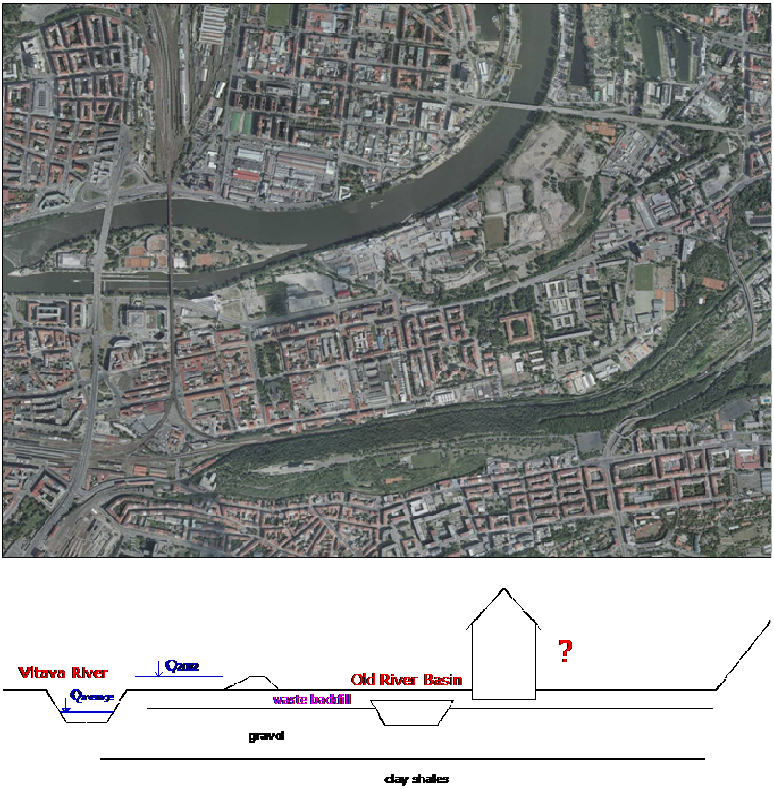


Figure 1.30: Prague – Karlin,Rohan – plan and cross section through area

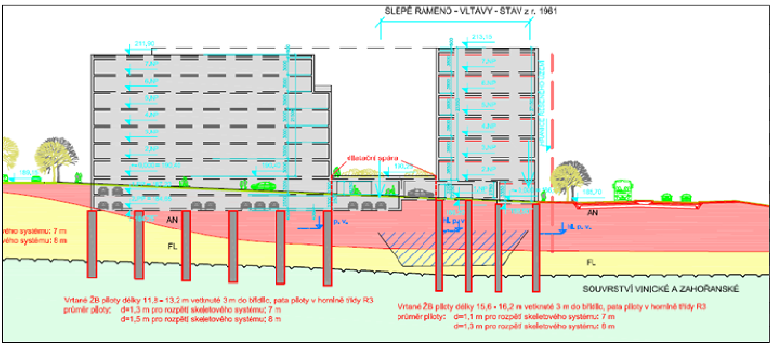


Figure 1.31: Karlin, Rohan –version with pile foundations in places with old river basin

1.8.5 *Utilization of landfill surface for new construction*

With the up to date philosophy of the sustainable construction to use brownfields as much as possible for new construction to safeguard greenfields, requirements for utilization of landfill surface will increase.

The example of combination of remediation of old chemical landfill with a construction of a new one on its surface is described by Vaníček et al, 2003. Neratovice old chemical landfill is situated north of Prague a few hundred metres from the Labe River.

Because the chemical factory also in the future has to store some waste material in this area it was decided that the remediation should be based on the following principles:

- To stop the contaminant spreading from the waste dump;
- To partly use the locality for storage of a new chemical waste material.

Classical remediation consists from the construction of underground sealing wall in combination with hydraulic barrier, with continuous pumping inside of the protected area to decrease underground water level there, Fig. 1.32. The horizontal sealing system above old stored chemical material is constructed by such s manner that can be used as a bottom sealing system for new chemical landfill and can also fulfil all higher demand on it. To reduce high settlement of old landfill material compression with help of dynamic consolidation method was used, Fig. 1.33. After compaction of subsoil the horizontal sealing layer was applied as “clay compacted liner”, and landfill was prepared to store another chemical waste material - Fig. 1.34.

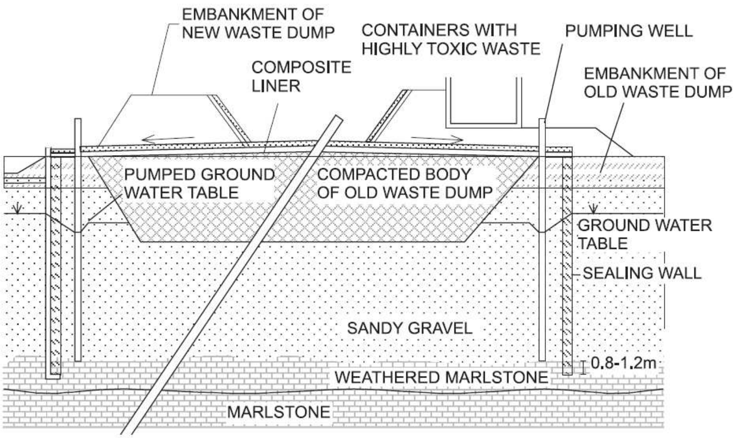


Figure 1. 32: Cross section of the Neratovice chemical landfill remediation with sealing system on the top for new landfill situated on the old one.

Figure 1.33: Compaction of old waste material with dynamic consolidation method.

Figure 1.34: Remediated surface of old chemical landfill is prepared for deposition of another waste.

1.8.6 *Constructions on spoil heaps*

Last case describes general problem of foundation new structures on spoil heaps composed from uncompacted clay clods as a result of opencast coal-mining. Huge amount of tertiary clays which overlay brown coal in the north part of the Czech Republic should be excavated and deposited on new places by free fall – Fig. 1.35, creating spoil heaps of extreme height (100 – 200 m). In this area the foundation of new structures on top of these spoil heaps is nearly necessity.

Figure 1.35: General view on spoil heap during its construction – by free fall filling

However some specificity of such deposited material can be defined, e.g. Vaníček I and Vaníček M (2008):

- free fall filling is more often a manner of spoil heap construction;
- deposited material has high porosity (macro-porosity) between individual clods;
- individual clods are sensitive to weathering;
- properties are time dependent, not only as function of weathering but also as the result of water saturation, depth of deposition etc.

It is obvious that there is a general tendency to store on 1 m2 utmost of material, therefore to construct spoil heaps as steep and as high as possible. This tendency brings high risk of slope instability, creating landslides with high potential risk to the surrounding area. Therefore the first condition for the construction on the surface of these spoil heaps is long term slope stability, especially for final level of ground water level and for extreme rainfalls, e.g. Vaníček and Chamra (2008). The second condition is connected with deformability of these spoil heaps with time not only due to own weight and also as result of additional loading from new foundations.

The settlement of spread foundations on spoil heap is composed from:

- settlement of spoil heap body;
- settlement of spoil heap basement;
- settlement in “active zone” beneath the foundation.

Usually two first components we can identify as settlement of the spoil heap surface. This component can be measured and is expressed in Fig. 1.36 as function of time t. To estimate what time to start with new construction we can use existing data. From the up to date experience we know that the final value of settlement of the spoil heap surface is roughly:

$s_b = (0.02 – 0.03)$ H

where H is total height of spoil heap. Lower values are valid for lower spoil heaps roughly H = 30 m, and higher values are valid for higher spoil heaps H = 100 m. From the time path the settlement is estimated as:

- 25-50 % of the final value during 1st year;
- 70-75 % within 5 years;
- 85 – 90 % within 10 years.

It seems that after 10 years after the finishing spoil heap filling that the most of the deformation is over, however we have to count still with some 300 – 450 mm what is much higher value than usually accepted. This problem has different levels of solution. Among passive measures we can count:

- postponing the new construction to decrease the value of ss,t – sometimes this condition is unacceptable;
- using some methods of deep foundations like piles – but solution can be limited by height of fill, by economical reasons and a negative skin friction be taken into account;
- preconsolidation with additional load, which has to be removed after a certain time – very problematic as it is connected with huge volume of additional fill and with time needed for which this additional loading have to be applied.

Among active measures the different approach is usually chosen for total and for differential settlements. Higher value of total settlement can be accepted if:

- special technical solution is applied for engineering services as electricity, gas, sewage…,
- rectification can be applied e.g. for railway tracks, pipelines etc.

But most sensitive questions are connected with differential settlements with direct impact on damages to the structural elements and to the manner of the practical use of the structures. There we cannot so easily accept little bit higher values as for total settlement. Therefore if the probability that the expected different settlements will be higher than the accepted ones this situation will have to be solved with the help of the following steps:

- to select such construction system which is not so sensitive to the differential settlements; or
- to improve the subsoil beneath foundations.

For the first case one extreme is wooden skeleton and on the other side of this spectrum is stiff “box type” of structure. For motorways the asphalt surface is usually preferred.

For the second case there are some possibilities how to improve the subsoil beneath foundations as

- classical compaction – when last metres of filling is not applied by free fall but classical filling with spreading material in layers, plus additional possibility of plane reinforcement by geosynthetics;
- dynamic compaction;

- injection, grounting, mixing of top layer of fill with additional material as e.g. ash to partly refill large macropores between individual clods;
- application of “clay piles”.

Especially last possibility was proved as very useful and was successfully applied in more cases. Pre-driven profile is backfilled by clay of similar properties as is surrounding material and subsequently compacted there.

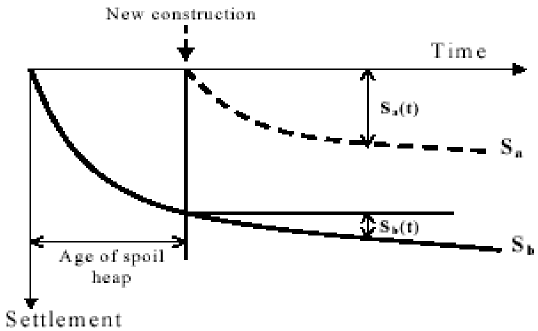


Figure 1.36: Settlement of spoil heap body and new foundations on its top as function of time.

However not all area of spoil heaps in this region will be used for new construction. Significant part of these “mining brownfields” will be transformed back into greenfields, or into blue-fields – in case that old pit after open pit mining will be flooded by water, creating artificial lakes – Fig. 1.37.

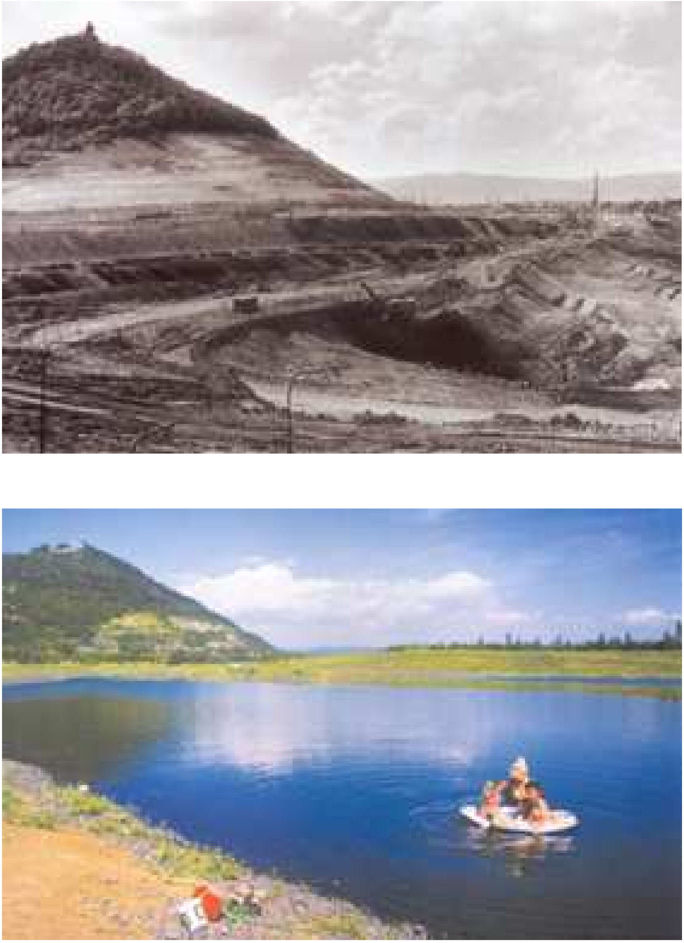


Figure 1.37: Change of mining BF into greenfields or blue-fields.

2 SUSTAINABLE CONSTRUCTION OF BUILDINGS

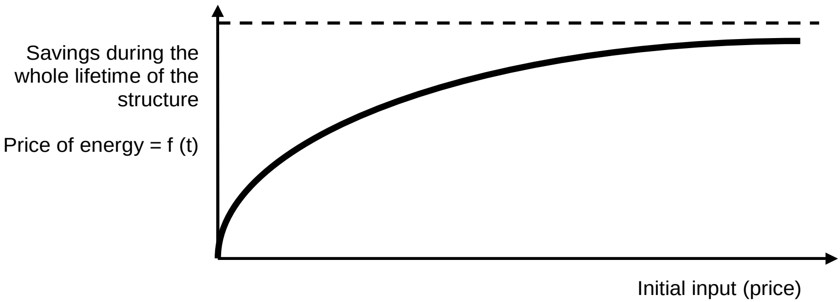
As people are spending very significant part of their life in building the problem associated with sustainable construction of buildings is extremely important. The main aim is to find a balanced relation between the building activities and constructions with the interior environment of good quality on the one hand and the environmental burden on the other hand in the whole life cycle of constructions - especially with the respect to building materials and a low energy consumption including renewable resources.

Starting point is associated with the fact that buildings during their all durability have extremely high share on the overall consumption of energy – about 30 to 40 %. Roughly it is the same percentage (30-40%) from the view of overall production of emission of CO_2 and production of waste. Therefore the main aim is there to decrease these values as much as possible.

2.1 *Ways to decrease energy demands*

There are different ways how to succeed however the main ones are:

- Architectural view;
- Construction system, including insulation from the view of heat, radon, noise
- Building equipments



- Additional sources of energy.

Nevertheless it is obvious that there must be multi-parametrical approach as economical factor is also very sensitive. Price for improvement – so called initial input - has a certain limit, as with initial input increase the savings during the whole lifetime of the structure are not proportional, they are little bit decreasing – see Fig. 2.1. The problem is that the price of energy is function of time and this function is difficult to predict.

Figure 2.1: Savings during the whole lifetime as function of initial input

2.1.1 *Architectural view*

Role of architects is very important first of all during the early stages of the design. Very often even when the initial (boundary) conditions are limiting factors in many cases, architectural view can significantly help, as the following aspects doesn't need necessarily to invest additional money:

- Building orientation – orientation to sun;
- Ratio between floorage and external wall surface;

- Portion of doors, windows;
- Shield component unit – to decrease overheating in summer;
- Accumulation units to absorb surplus of heat during day to use it during night;
- Interior lay-out;
- Green vegetation, e.g. Hlavová Gazdová, 2008 .

Building showed on Fig. 2.2 . is fulfilling most of the above mentioned factors.

Figure 2.2: Building in Roztoky, Arch. J. Horný

2.1.2 *Construction system*

In principle there are two main approaches from the view of construction system – skeleton construction system and masonry construction system.

For skeleton system the load-bearing skeleton is either from steel, concrete, timber or aluminium and as insulating component usually rock (glass) wool and polystyrene are now preferred. After many different evaluation the timber skeleton, especially for low floor buildings, can brings many savings. Timber skeleton system has lowest demand on energy during life expectancy and is composed from renewable structural material, Fig. 2.3. More details are presented by Tywoniak, 2007, 2011; Kuklík, 2011; Staněk, 2011.

Figure 2.3: Typical view on the timber skeleton system – J.Tywoniak

Second, however oldest construction system is masonry system, Fig. 2.4, historically stonework masonry, followed by kiln bricks. Nowadays the following 3 systems dominate, which are able to guarantee high quality from the bearing capacity and insulation views, Fig. 2.5:

- Kiln bricks – perforated air- bricks with high shape accuracy;
- Aerated concrete blocks;
- Blocks from expanded clay;

For further insulation improvements kiln bricks and blocks from expanded clay are also supplemented by polystyrene – Fig. 2.6

Figure 2.4: Masonry system from blocks from expanded clay

Figure 2.5: Basic components of the masonry system

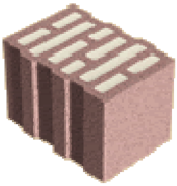


Figure 2.6: Block from expanded clay supplemented by polystyrene

2.2 *Quality of internal environment*

Temperature microclimates, quality of internal air together with construction details as temperature bridge and condensation point, have most significant impact on quality of internal environment. The quality of windows, doors and details of their connection with construction system are playing there very important role.

Quality of temperature microclimate is strongly affected by selected heating system – starting from local source of heat as different stoves using timber, coal, electricity (heat storage stove); fireplace using timber, wooden pellets, electricity, gas via central heating systems utilizing electricity, gas, coal to floor heating etc.

Quality of internal air is function of many aspects as quality of external air, volume of internal air per person, air exchange, ventilation system, amount of pollutants in air (coming also from persons, building materials, internal equipments etc.), Papež, 2011; Smažilová and Papež, 2011; Papež, Kabrhel and Jordán 2009; Kabrhel and Adamovský 2011, Svoboda, 2011. In the Czech Republic special attention is devoted to the protection against radon, as geological conditions in some areas are prone to the radon emanation. Actually in some cases the construction materials can be the source of this radon emanation. The protection against radon is using two basic principles, the utilization of strong isolation against radon penetration, or the utilization of special ventilation system e.g. in the foundation slab, Jiránek and Fronka, 2008; Rovenská and Jiránek, 2011.

From the view of air exchange there are two basic principles:

- construction system (skeleton) has air tightness sealing, usually with the help of plastic membranes, where exchange of air is via heat exchanger – this system has generally low accumulation capacity – when habitants are out of building the temperature can drop significantly, however can be increased very quickly on demanded value.
- Construction system (masonry) is partly permeable for air, has very high accumulation capacity and can be supplemented by micro-ventilation system, which can be operated as function of inside humidity, CO_2…

2.2.1 *Energy demands*

In the phase of building operation the energy demands from the view of building utilization strongly depends on:

- heating (cooling) and ventilation;
- consumption of hot water

The main principle results from the following expression:

Overall demands – own resources = outer demands

With decrease of overall demands and increase of own resources the outer demands can be reduced. In doing so the overall demands for heating (cooling) and ventilation depend on the construction system, quality of windows and doors together with details of their tacking - generally speaking depend on loss of energy of external building perimeter, very often expressed as $kWh/m^2.a$ – energy loss per square meter per year.

During last period a great attention is devoted to the additional resources of own energy, which can be obtained either from solar energy, or from geothermal energy or from energy of wind as well.

Buildings after that can be from the view of heating (cooling) and ventilation classified according to the energy demands as with:

- standard energy demands;
- low energy demands;
- passive houses (buildings) – less than 15 $kWh/(m^2.a)$
- zero energy demand – Tywoniak, 2011.

Additional note have to be added. Electric devices as TV, PC, freezer etc. can play positive role in winter and negative role in summer.

2.3 *Additional sources of energy*

As mentioned before the main sources of additional energy are solar energy, geothermal energy and energy of wind. The application of energy of wind for individual purposes is a great exception as it is the same for energy of water. Therefore the main attention is devoted to the solar and geothermal energies.

2.3.1 *Solar energy*

Buildings are receiving very important part of the solar energy as a natural source – owing to direct exposition of the sun. Architectural view – see above – is therefore very important. New engineered systems can be divided to:

- Photo-thermal systems, where energy of sun is transferred to heat. Water is usually used as the recipient of this energy and can be directly used or partly stored for future purposes in accumulators;
- Photo-voltaic system – which is able to transfer solar energy to electric energy

The design of these systems needs very careful optimisation as paradoxically the problem can start with surplus of energy, e.g. from photo-thermal systems during summer time, when hot water can be used only for washing, not for heating. Outer swimming pools are often used as solution of this problem, see Fig. 2.7.

Figure 2.7: Utilization of surplus energy for warming water in the swimming pool

Electric energy from photo-voltaic system can be used directly, or for small amount can be stored in accumulators or is connected to grid. Last case is preferred, nevertheless requires the negotiation with grid owners. Fig. 2.8 is showing experimental photo-voltaic system incorporated on the building of the Faculty of Civil Engineering CTU in Prague- Ženka, 2008.

Figure 2.8: Faculty of Civil Engineering – incorporated experimental photo-voltaic system – Tywoniak , Ženka

2.3.2 *Geothermal energy*

Geothermal energy utilizes the heat energy which is stored in the centre of the Earth and is decreasing with decreasing distance from the surface. Therefore two different levels of geothermal energy can be specified:

- High potential energy can be used directly only in countries with significant volcanic activities as Island or New Zealand, as in this case the Earth surface is connected with greater depth by different preferential paths. In other cases in many other countries investigation started to find places where high energy (temperature) is in reachable depth (about 2 to 5 km). However in this case this extracted energy will be used in larger scale not for local buildings directly.
- Low potential energy which can be used directly for energy consumption in individual buildings.

Practical exploration of low potential energy has now three different levels:

- Earth aerial heat exchanger (supply of fresh air by pipes embedded in subsoil) which is bringing important savings in energy as supply air is heated during winter and cooled during summer, Jílková, 2011. Depth of this exchanger should be at least 1.2 – 1.8 m (non freezing depth) and the length about 30 – 40 m. After that the supply air with temperature about – 20^0 C can have at the building entry temperature slightly about zero.
- Systems utilizing heat pumps for heating and where preheated medium is either air or liquid. For preheating are used either horizontal areal collectors in low depth or deep vertical wells. Efficiency is given by ratio of demanded energy to the obtained energy. Better efficiency is obtained for deeper wells however again the initial investment is higher.
- Systems utilizing heat reversible pumps either for heating or for cooling. This system is preferred for larger objects where cooling during summer is very important. Typical examples are energy piles or diaphragm walls. As this system is not typical for the Czech Republic (as the previous two ones) therefore will be described in more details. The experience from Austria described by Brandl (2008) will be presented on practical examples.

2.3.3 *Energy piles and diaphragm walls*

Application of energy foundations brings new innovations and hence also a certain risk. Investor (client) is responsible for the first step, as this solution can bring important energy savings but again with higher financial input and as a rule any innovation brings higher risk.

Final decision should be made at early stages of the structure design as on the armature of piles or diaphragm walls the network of pipes through which the liquid is passing through should be connected, see Fig. 2.9.

Seasonal operation of energy piles is schematically shown on Fig. 2.10. For the initial situation the subsoil temperature is approximately 8 – 12^0 C. During summer time warmer fluid from building is transmitted in pipes to the subsoil. Temperature there is increased and temperature of fluid in pipes is decreased. At the beginning of autumn a

Figure 2.9: Connection of pipes to piles and diaphragm walls armatures. (Brandl 2008).

certain amount of heat was accumulated in the subsoil and temperature there is about 12 to 16^0 C. Therefore during winter accumulated heat in subsoil is used for building heating so that in spring the temperature is subsoil is down to 4 – 8^0 C and is prepared for building cooling and energy accumulation. All process is directed by energy centre with reversible heat pump and temperature transfer is done in slabs, concrete core respectively.

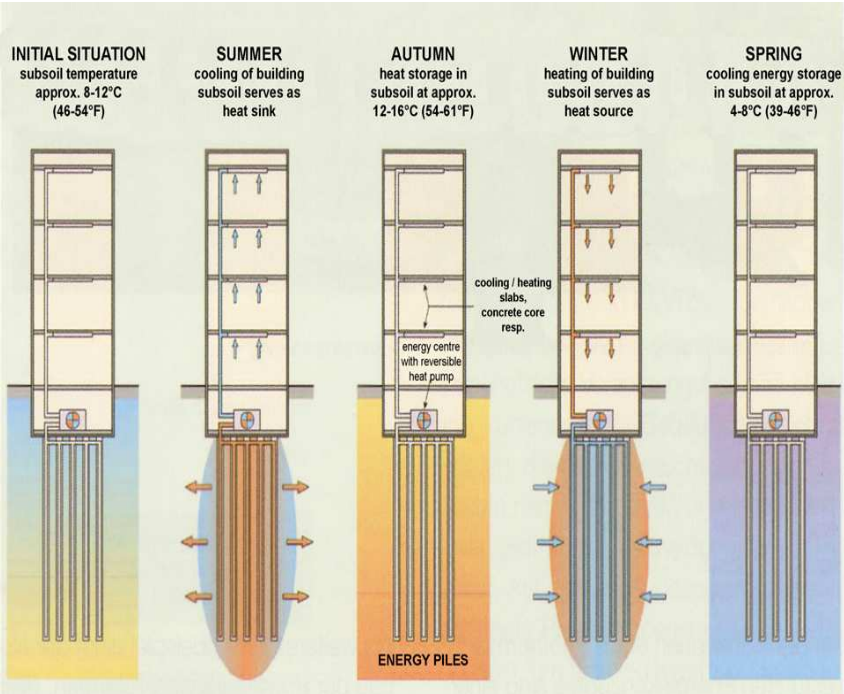


Figure 2.10: Principle of energy piles operation in different seasons.

History of the temperature changes in fluids inside of pipes on outlet from subsoil for one year together with heating/cooling loads respectively heating/cooling capacity is shown in fig. 2.11.

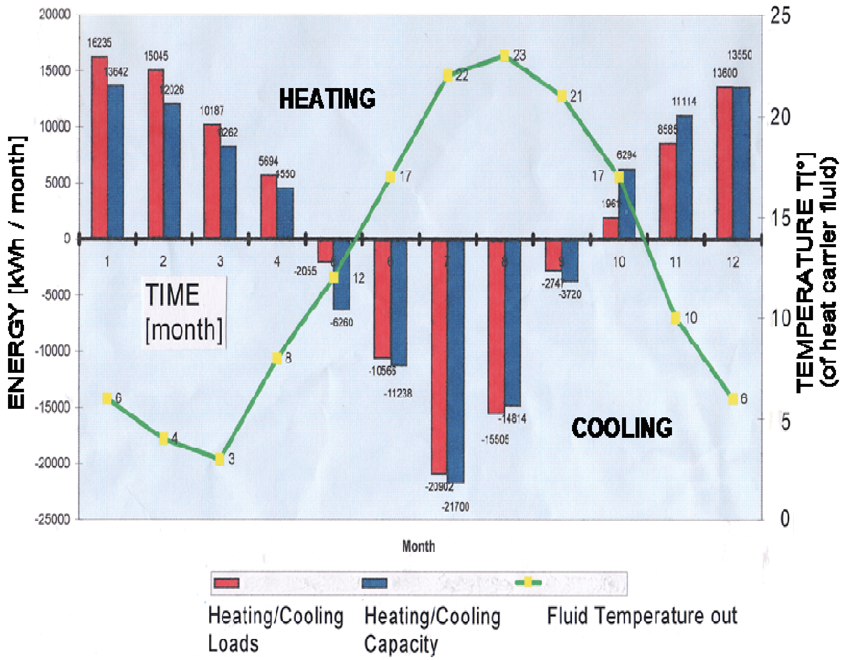


Figure 2.11: Temperature and energy changes observed for heating and cooling period.

On fig. 2.12, 2.13 and 2.14 are shown another examples presenting different ways of application. For the last case for large hall which can be used for exhibitions, fairs or as a sport hall applied energy piles for heating and cooling can save annually nearly 100 000 m^3 of natural gas.

Another possibility presents the case of motorway passing directly from the bridge to the tunnel. When first part of the tunnel is constructed with cut and cover methods, energy diaphragm walls can help to heat the bridge deck to protect surface against iciness.

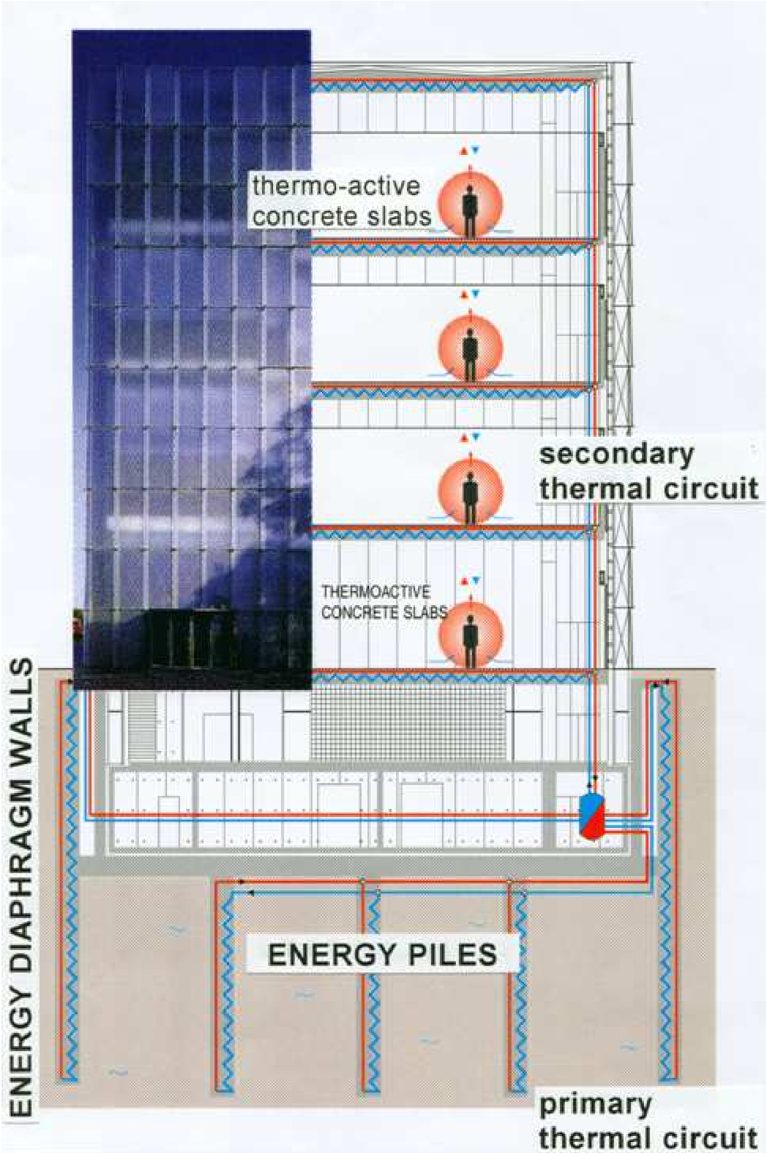


Figure 2.12: Application of energy foundations for administrative building

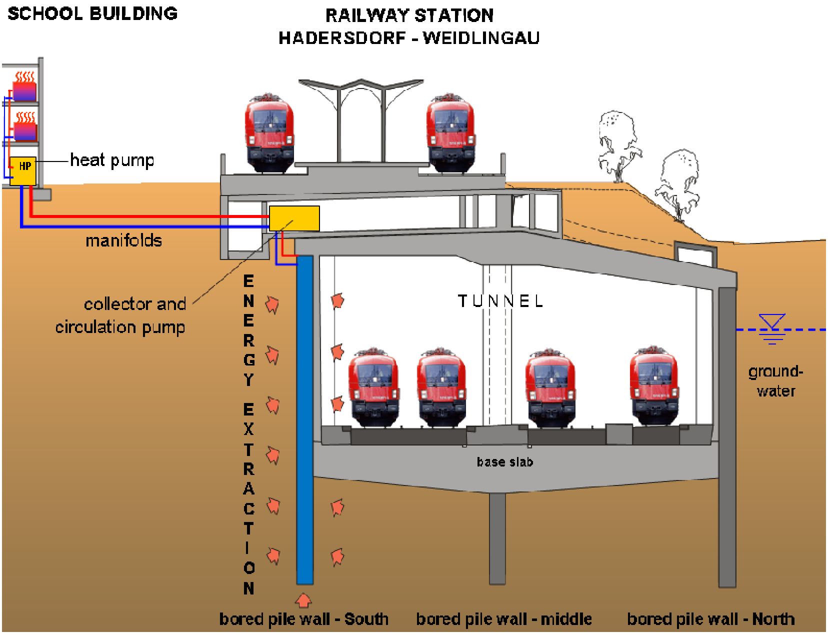


Figure 2.13: Energy transfer from pile walls of the tunnel to the school building.

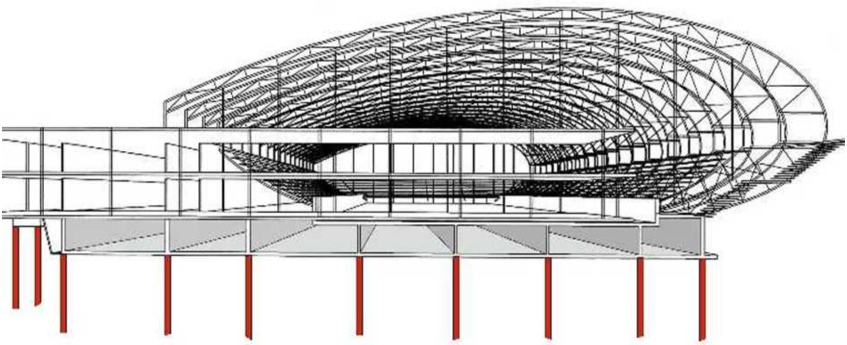


Figure 2. 14: Energy piles for heating and cooling of multifunctional hall.

2.4 *Sustainable Construction of Buildings – Conclusion*

From the presented overview, as some specific problems are described in Volume 2 of the presented set of the books on problem of Sustainable construction, it is obvious that the complex approach is needed. Different partners have to combine their activities as on:

- Governmental level – e.g. Project "Green light for Energy saving" or via "Energetic Audits" – as the price of building for the future will strongly depend on the amount of energy needed for their utilization (and later on their demolition);
- Research level – as is e.g. our Research project "Sustainable Construction";
- Level of practical application – especially via different codes and standards;
- Levels of International cooperation as solved problems are very similar for each country, especially in Europe.

3 WASTE, RECYCLED MATERIALS UTILIZATION

3.1 *Basic principles*

Human activities produce a huge amount of different waste. Therefore the most important aim is to decrease the volume of such waste. Second question is after that connected with waste strategy:

Basic principle

Waste Deposition	**Waste Utilization (as much as possible)**

After it two basic items have to be investigated:
Construction item - Mechanical properties of the waste
Environmental item - Character of leachate from the waste

During previous part of the project with title "Environmental aspects in Civil Engineering" the attention was devoted to the safe storage of the waste material in the form of different landfills, tailing dams, spoil heaps and underground repositories, especially from the view of protection barriers restricting the contamination spreading from the place of deposition.

How huge areas are covered by deposited waste can be seen from Fig. 3.1 for spoil heaps composed from the material which overlay seams of brown coal (lignite); from Fig. 3.2. for tailing dams as for Mydlovary, where waste material from uranium ore concentration factory is stored and finally from Fig. 3.3. showing one of the many municipal sanitary landfills - landfill in Dablice – Prague.

Figure 3.1: View on the spoil heap surface – North Bohemian brown coal basin


Figure 3.2: View on the Mydlovary tailing dams


Figure 3.3: View on the municipal landfill in Dablice - Prague

Now the attention is devoted to the problem of waste or recycled materials utilization, on application in Civil Engineering, e.g. Kulhánková, 2011, especially on large volume waste as:

- Construction – demolition waste – old bricks, concrete, ceramics, old asphalt pavement, gravel ballast; e.g. Škopán, 2011; Lukš, 2011 and Pokorný, 2011;
- Industrial waste – ash, dross, slag, e.g. Lidmila, 2011; Mráz, 2011;
- Mining waste – overlaying soils, waste rock, quarry waste, residues after washing china clay…

During last period the orientation is also on other relatively large volume materials as tyres, glass, polystyrene…

The discussion about excavated soil is still going on, whether we have to look on it as on the waste material or not, what quick and cheap methods of control of possible contamination can be used.

In the first place the producer of the waste should have have the interest to find practical application for waste, as it is not only environment friendly solution but in many cases also financially attractive solution.

Practical application can have different manner of utilization:

- Without any improvement – for example old tyres can be used directly in protection barriers against rock fall as will be shown in chapter 4;
- With significant changes of the waste character – e.g. for above mentioned tyres, they can be crushed down and small particles can be used as additive material for new asphalt pavement
- Waste can be used for new construction material – e.g. aggregates of some large volume waste can be used for new concrete or glass after reprocessing in the form of foam glass has extremely interesting properties due to low density, high insulation properties and low absorptiveness.

However in many cases the producer is trying to use waste material directly (or to offer–to sell it to the second potential user), though many electric power stations producing large volume of ash are trying to modify it to have better chance to find the application for such waste.

3.2 *Support for waste utilization*

Fundamental condition for large volume waste utilization is connected with database about

- Volume of waste, place of production, respectively the place where such waste is stored. Example is Fig. 3.4, where the total volume of waste (masonry demolition and concrete demolition waste) is shown as function of time (years), Vodička and Šeps, 2011. For the Czech Republic the total number of these waste is together more than 3.5 mil. tonnes which are now to the disposal at 160 operating recycling plants, either permanent or portable facilities, see Fig. 3.5;
- Declaration of the material properties especially from the mechanical characteristics point of view
- Declaration of the environmental properties – firstly quality of leachate.

All these information are prerequisite for potential opening of the commodity exchange, ensuring the balance between supply and demand, e.g Liška and Gazda, 2007; Gazda et al.,2008, Liška et al, 2011.

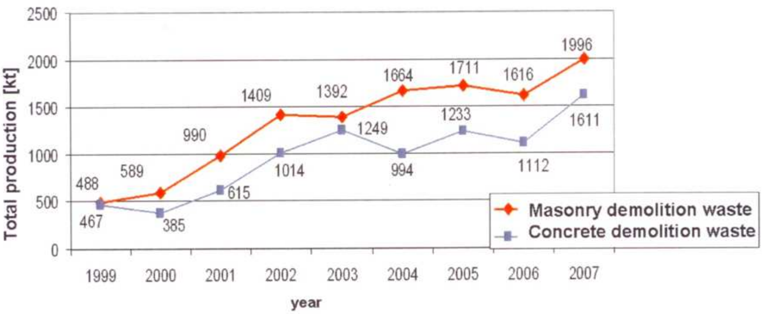


Figure 3.4: Production of masonry and demolition waste during last decade

Figure 3.5: Recycling plant in operation

Most often manner of waste utilization is substitution of naturally occurring aggregates – firstly gravel sand, namely as alternative material (aggregates) for:

- Concrete (after size separation);
- Earth structures – giving in this direction new view on the balance between volume of cuts and embankments, e.g. for new motorways;
- Ground shaping;
- Improvement of underlay of new access path, roads, etc.

Nevertheless it is at the same time to be very careful whether there are some restrictions or not. For example for construction and demolition waste it is volume of wood, for un-weathered slag it is disposition to heave (swelling). We have to be careful as e.g. ash from different electric power stations can have different properties, also as result of different methods used for desulphurization process. In some cases also transport expenses can be by this a limiting factor.

3.3 *Examples of practical applications*

Below only few examples will be presented, firstly problems which were solved during research project “Sustainable Construction”, namely utilization of ash in transport engineering and utilization of construction and demolition waste for new type of concrete.

3.3.1 *Utilization of flying ash in earth structures of transport engineering*

Burning of solid fuel for production of electricity and heat is still prevailing manner of the production of energy in the world. Also in the Czech Republic this rate is very high, reaching up to 75 % of energy consumption. Therefore the production of sediments resulting from the solid fuel burning is high per habitants, roughly 1.1 t per year. The reason is either high ash content coming from brown coal or high energetic demand of the industry in the CR. The utilization of ash in earth structures of transport engineering is one of the most important ways how to decrease the volume of ash deposited in tailing dams.

Generally there are two options for the use of ash in embankments, either the full internal body of the embankment is built from ash or the embankment core is built in layers, inter-bedding the waste material with "normal" soil layers – see Fig. 3.6. Usually the second type is called sandwich construction. In this type of construction the "normal" soil is usually represented by fine grained locally won soils that do not have good shear strength properties because the waste material can have them much better. Another advantage of using clayey soil in the sandwich embankment is their capacity of sorption of some of the substances in the leachate, Vaníček, I. and Vaníček, M. (2008).

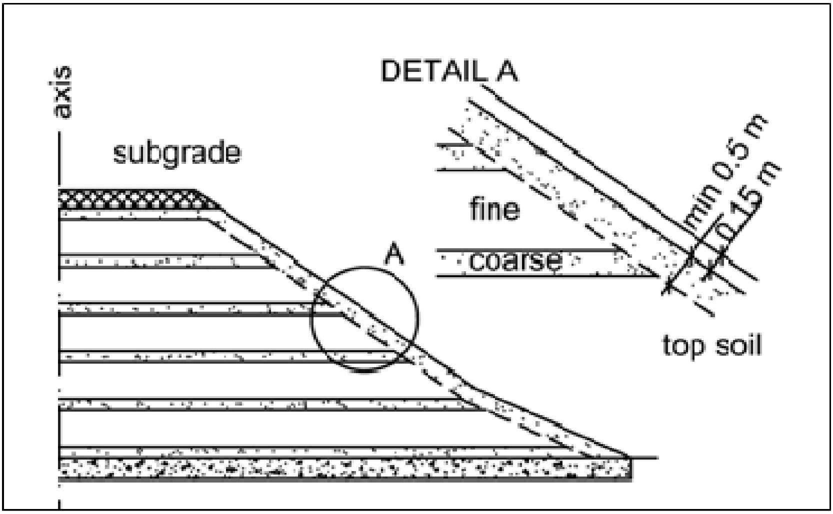


Figure 3.6: Sandwich embankment, coarse layers are composed from flying ash.

With respect to limit state design (overall stability, settlement) ash does not have negative influence, because its properties (shear strength, modulus of deformation) are in the range of natural soils used in such structures. On the other hand its higher permeability can speed up in some cases consolidation process of the embankment itself. However more sensitive for ash is the limit state of surface erosion as the material is composed mostly from fine grains, with low volume density. Therefore it is recommended not to use it directly on slopes. Materials should be under the protective layer of surrounding materials and grassed topsoil.

From the contaminant transport point of view we need to gather the information about the waste leachate composition and parameters for contaminant transport modelling. The leachate composition is done on source by source basis; of course for the same type of waste, we can assume certain general properties. And again for modelling parameters those should be determined on project basis.

For proposed embankment – see Fig. 3.7., environmental study was performed. Leachate analyses proved that in some cases (e.g. for pH, PAH, Arsenic, Cadmium) obtained values are higher than as limit defined by National Environmental Agency. Therefore it was necessary to guarantee that degree of contamination when reaching brook, will be lower than demanded limit with high probability (let say 10^{-4} – 10^{-7}).

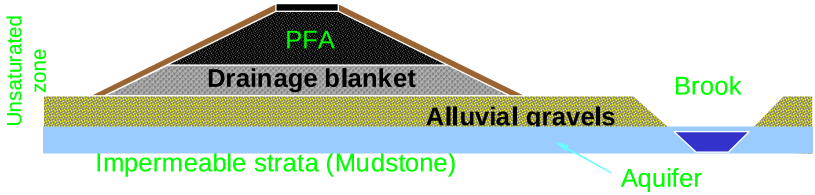


Figure 3.7: Proposed embankment for which experimental study of contamination spreading was performed.

For the risk assessment a probabilistic analysis using computer programme CONSIM (recommended by the UK Environmental Agency) has been used. The stochastic part of the solution in CONSIM is based upon the Monte Carlo method, which means that the model is analysed several thousand times with randomly generated input parameters that satisfies the entered probability distributions. The results of the CONSIM program are expressed as function of probability in which the contaminant with certain concentration can reach the aquifer at given time. One such example is shown in tab. 3.1.

Concentration (mg/l)	0.05	0.10	0.15	0.20
Probability (-)	0.20	0.015	0.001	1.10^{-4}

Note: For chromium the limit value is 0.05 mg/l

Table 3.1: Concentration of Chromium reaching the brook after 10 years as a function of probability

3.3.2 *Utilization of ash in pavement structure or in track substructure*

During the last decades most of the electric power stations in the Czech Republic installed new desulphurization systems. The most often used systems are:

- Wet lime washing method – which is preferred for bigger electric units. There combustion gas is mixed with water and with mixture of fine milled limestone;
- Fluid burning – which is preferred for smaller units. There fine filled coal is mixed with fine milled limestone and this mixture is burned together.

Remaining parts after fluid burning contain relatively high percentage of free CaO. The resulting product has a greater potential to hardening and can be used directly in some civil engineering application. Remaining parts coming from wet lime washing method contain the slag, ash, energy-gypsum and waste water. The amount of particular remaining components and the ratio of them are determined by the size and type of boiler. These amounts and the ratios of particular components may, however, be substantially changed if some particular component is either fully or partially utilised as a secondary raw material (e.g. energy-gypsum for manufacturing of plaster-board construction units). Therefore remaining parts can be used directly in civil engineering applications or after mixing with additional additives (cement, lime).

Fig. 3.8. is showing the compaction of ash in track bed. Sometimes there is a problem connected with optimal moisture content determination as for ash the character of Proctor curve, their peak, is not so obvious as for classical soil.

Figure 3.8: Ash compaction in track bed.

Stabilized ash is also prepared, transported and deposited in so called “wet” form, see Fig. 3.9. With the help of additives the strength is increasing rather quickly.

Figure 3.9: Deposition of the stabilized ash in the “wet” form for the road foundation

Nevertheless the final product is a rather brittle, sensitive to the crack formation. To improve the flexibility new experiments with ash reinforced by micro synthetic fibres started and are concentrated not only on mechanical properties but also on the technology of mixing. Cross sections of samples prepared for triaxial tests are shown in Fig. 3.10.

Figure 3.10: Ash reinforced by micro synthetic fibres.

Fig. 3.11 shows the static load test by small plate on experimental part of railway track where ash was applied under track bed (ballast), e.g. Lidmila, 2007, 2011.

Figure 3.11: Verification of deformation characteristic of ash used in track substructure

3.3.3 *Utilization of construction and demolition waste*

Main parts of the construction and demolition waste are composed from old concrete and bricks, sometimes with smaller amount of ceramics, plaster or wood. Last component is undesirable and its amount should be limited as much as possible. At the collection spots waste material is crushed and after sieving divided into different fractions, see Fig. 3.12.

Direct utilization as substitution of natural aggregates is possible only in the case of well quality of concrete. Different possibilities of concrete recycling are described by Výborný, 2011. Therefore probably the better way how to use the recycled waste is the utilization without special adjustment (even without sieving and separation into different fractions). To compose from this untreated waste new construction material with specific properties for which the application can be found later on.

One of such new material which was experimentally verified during research project is so called brick – fibre – concrete which is composed from old bricks and concrete crushed particles together with classical additives for concrete – cement and water and with new additives – with synthetic fibres – Fig. 3.13, e.g. Vodička et al, 2009; Výborný, 2011; Vytlačilová, 2011; Hanzlová and Šeps, 2011; Vodička and Šeps, 2011.

Figure 3.12: Crushed parts of old concrete and bricks

Figure 3.13: Different synthetic fibres applied for brick – fibre – concrete

After mixing together the final product looks like on the Fig. 3.14, where interconnection of individual components is visible. The degree of compaction can significantly determine the final result – what is for example very important from the view of permeability, as this property can be guarantee in relatively wide range.

Figure 3.14: Mixture for the preparation of brick – fibre – concrete

Experimental beams were prepared for testing. Fig. 3.15 is showing the bending test and the character of beam profile is visible from the Fig. 3.16. From this photo it is evident that fibres are playing very important role. Fig. 3.17 compares the results for unreinforced and reinforced samples. Unreinforced sample shows rapid drop – off of the strength after maximum value.


Figure 3.15: Bending test on experimental beam

Figure 3.16: Character of beam cross section after the failure

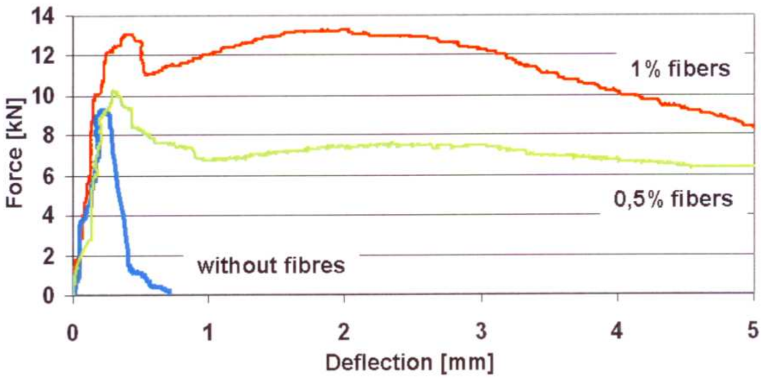


Figure 3.17: Influence of synthetic fibres on the strength parameters and behaviour after failure.

3.3.4 *Utilization of brick – fibre – concrete for earth structures in water engineering – for small dams, dikes*

As classical reinforced embankments can be reinforced by geosynthetics, similarly earth structures in water engineering can be reinforced by layers from brick-fibre-concrete. The impact on seepage through such dam, dike, can be eliminated, as above mentioned; the permeability of new product can be partly directed.

Embankment in this case can have significantly lower volume, saving not only volume of construction material but also piece of land, what is nowadays very important factor, Fig. 3.18.

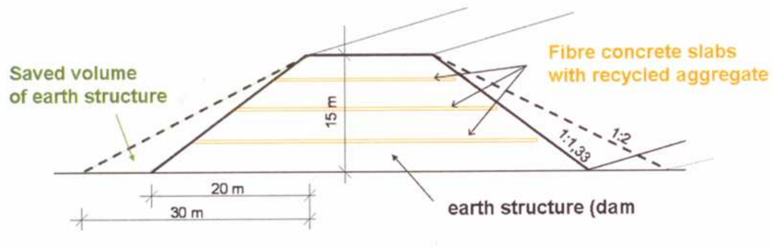


Figure 3.18: Comparison of two cross sections of embankments without and with reinforcement

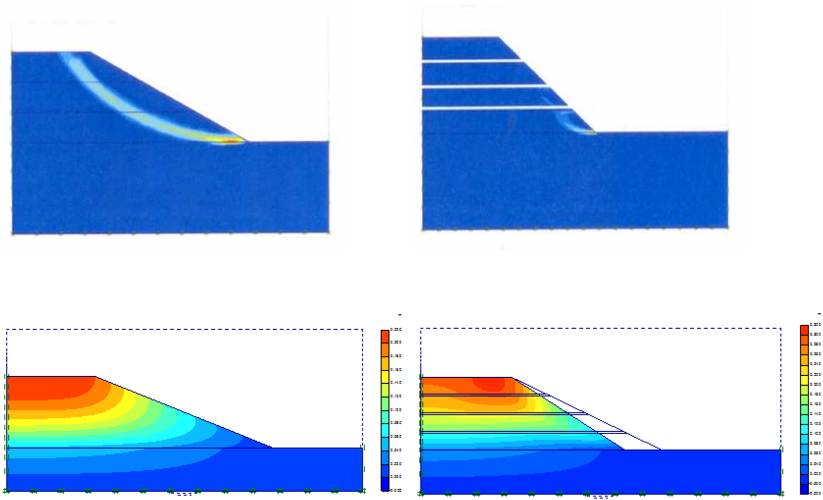


Figure 3.19: Results of the numerical modelling of the stress changes and deformation changes

For above mentioned two cross sections from the Fig. 3.18 the numerical analysis (stress analysis) was performed, Hrubý, 2011 and for embankment with reinforcement and with steeper slope the areas with stresses close to stresses at failure are much smaller than for slope without reinforcement, Fig. 3.19.

After that the reinforced slope was proposed as flood protection system, Vodička et al, 2009. Brick-fibre-concrete was applied not only inside of the embankment body, but also at the crest of a dike. Large models were prepared either for reinforced and unreinforced embankments and the resistance against surface erosion was tested. Unreinforced embankment failed very quickly while the reinforced embankment resisted for many hours. Only small erosion between reinforcing layers were recorded – Fig. 3. 20 and 3.21. So the new solution for dikes can be very efficient, especially in cases where only part of dike is reinforced, in selected place, where the crest of dike is decreased against the rest of the crest. So in this selected place the overflowing start earlier and have positive impact on the stability of the rest of the dike.

Figure 3.20: Model of reinforced dike before the test started.

Figure 3.21: Model of reinforced dike after long term overflowing.

3.3.5 *Asphaltt pavement recycling*

Last note is connected with recycling of materials used in civil – transport – engineering. During last period a great attention is devoted to the asphalt pavement recycling, Fig. 3.22, 3.23 and 3.24, where two different ways can be selected for:

- Recycling under the hot or warm conditions, Mondschein, 2011;

- Recycling under cold conditions, Mondschein, 2006; Formanová, 2011;

During railway ballast recycling procedure (during which smaller crushed down particles are removed) the utilization of bitumen emulsion can be useful solution, e.g. Kučera and Lidmila, 2009. Laboratory test were performed also with old crushed concrete or ash which can substitute classical ballast, Kučera, 2011.

Figure 3.22: Hot asphalt mixtures recycling

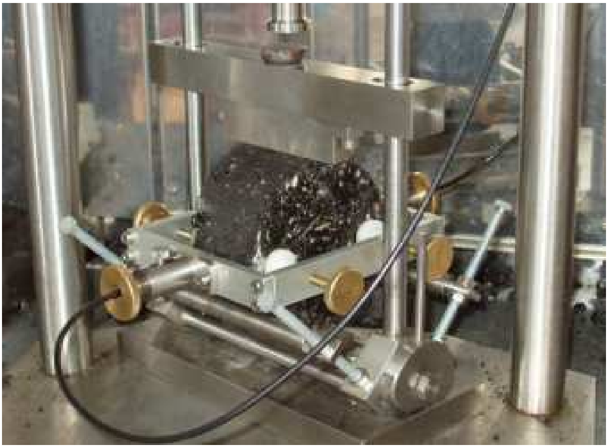


Figure 3.23: Testing of recycled asphalt mixtures prepared under hot conditions

Figure 3. 24: Cold asphalt recycling in-situ

4 NATURAL HAZARDS (CALAMITIES, ACCIDENTS) – OPTIMISATION OF PROTECTION, INTERACTION WITH STRUCTURES

4.1 *Introduction*

During last two decades a great attention is devoted to different natural disasters. E.g. Kalsnes, Nadim and Lacasse (2010) are writing about 8 866 disasters causing 2.3 million fatalities for the period of 1975 and 2008. However since 2008 many other disasters caused many problems all over the world, as in Myanmar (tropical cyclone), earthquakes in China (2009) Chile, Haiti, New Zealand (2010), Japan (2011) combined with tsunami etc. Nevertheless when the trend of fatalities due to natural hazards is studied over the last 100 years, it appears that the increase in the known number of deaths is due to the increase in the exposed population in this time scale and the increased dissemination of the information, and not to an increase in the frequency and/or severity of natural hazards. From the view of protection it is important to mention another fact. Several well-documented studies have shown clearly that developing countries are more severally affected by natural disasters than developed countries, especially in terms of lives lost. Kalnes, Nadim and Lacasse show also table from which this fact is clearly visible.

Country classification	No. of disasters	No. of disasters
Low and medium developed countries	1838	649 400
Highly developed countries	719	16 200

Table 4.1: Natural disasters between 1991 – 2000

In highly developed countries accepted a proactive approach to risk management, which can help to reduce loss of lives and material damages associated with natural hazards. Preventive measures are directed at:

- better forecast of individual event
- strengthening of the resistance of structures
- methodology how to behave during such events

For example for floods the first point is connected with floods time forecast, with forecast of areas which can be flooded so that people are better prepared in advance. Second point is connected with reinforcement of dikes, with construction of additional reservoirs and also with all measures which can increase land adsorption capacity. The significance of the last point can be shown on comparison of the floods in the Czech Republic in 1997 and 2002. Although in 2002 floods affected larger part of country and were associated with more extreme rainfalls 17 people died compared to 60 in 1997. Reason of this fact is partly accounted to new law (239/2000) and to better organization and equipment, especially from the view of “Integrated Emergency System” (IZS).

4.1.1 *Risk assessment*

Terminology:

- Danger: Phenomenon that could lead to damage;
- Hazards: Probability that a particular danger (threat) occurs within a given period of time;

- Risk: Measure of probability and severity of an adverse effect to life, health, property, or the environment. Mathematically, risk is defined as Risk = Hazard x Potential worth of loss;
- Vulnerability: The degree of loss to a given element or set of elements within the area affected by a hazards. It is expressed on a scale of 0 (no loss) to 1 (total loss).

Quantitatively risk can be evaluated from the following expression:

$$\mathbf{R = H \times V \times E}$$

where
- E is expected cost of total loss of elements at risk;
- H is hazards
- V is vulnerability of elements at risk and
- R is risk associated with a particular danger

Expected cost is for highly developed countries are higher as costs of the elements at risk (property and human lives) are evaluated much higher than in the rest of the world. Therefore the investment – price of preventive measures - can be much higher and therefore also more efficient.

Final decision is influenced by many different aspects so that it is necessary to pass through the all process of risk management process, e.g. Lee and Jones (2004):

- Danger Identification – what are the dangers and their magnitude;
- Hazard Analysis – how often can the dangers of a given magnitude occur;
- Elements at Risk Identification – what are the elements in risk;
- Vulnerability Assessment – what is the potential damage to the elements at risk;
- Risk Estimation – what is the probability of damage;
- Risk Evaluation – what is the significance of the estimated risk;
- Risk management – what should be done.

Last point is connected with responsibility for final decision, should this decision be done by engineers only or also by politicians or by public generally. The reality is that for structures which are connected with protection against natural hazards politicians (government, local municipality) and even potentially affected population also play an important role, Vaníček (2011). In the Czech Republic after heavy floods in 2002 some local municipalities approved the construction of supplemented measures for higher floods, 200, 500 even 1000 year floods, whereas paradoxically for the protection of towns mobile barriers, whose life time expectancy is only a few decades, are also used, see Fig. 4.1 and 4.2.

Figure 4.1: Mobile barrier applied during heavy floods in Prague 2002.

Figure 4.2: Testing of new mobile barriers in historical part of Prague

After this introduction basic practical examples for natural and man-made hazards will be presented, namely with respect to the research project outputs.

4.2 *Natural hazards*

4.2.1 *Landslides*

Landslides represent a major threat to human life, property and constructed facilities, infrastructure and natural environments in most mountainous and hilly regions of the world. Statistics show that landslides are responsible for at least 17 % of all fatalities from natural hazards worldwide. The socio-economic impact of landslides is underestimated because landslides are usually not separated from other natural hazards triggers, such as extreme precipitation, earthquakes or floods. This underestimation contributes to reduced awareness and concern of both authorities and general public about landslide risk – Kalsnes, Nadim and Lacasse (2010).

However landslides are not only connected with mountainous areas but also with man-made activities, different cuts and embankments. In the Czech Republic special attention is devoted to areas with anthropogenic deposits – as for spoil heaps, tailing dams, landfills, which were mentioned on Fig. 3.1., 3.2., 3.3.

4.2.1.1 Stability of spoil heaps

Roughly 200 mil. m^3 of clayey material which overlay brown coal seam are removed and backfilled during open pit mining activity in the Czech Republic each year, Fig. 4.3., 4.4.

Figure 4.3: General view on open pit mine

Figure 4.4: Character of clay clods after deposition

Figure 4.5: Weathered clods

As extremely large part of the country in this area is affected by mining activity the construction of new structures on the surfaces of these spoil heaps is nearly necessity. However some specificity of such deposited material can be defined, e.g. Vaníček I and Vaníček M (2008):

- free fall filling is more often a manner of spoil heap construction;
- deposited material has high porosity (macro-porosity) between individual clods;
- individual clods are sensitive to weathering; Fig. 4.5;
- properties are time dependent, not only as function of weathering but also as the result of water saturation, depth of deposition etc.

From the view of remediation of this area, slope stability should be secured even for long time period. Part of remediation process is also creation of new artificial lakes, fulfilling pit after coal excavation. With water table increase the stability the neighbouring slopes is decreasing and therefore monitoring combined with stability calculation are very important.

4.2.1.2 Monitoring

Large monitoring system was applied for Rabenov area, close to the town Ústí nad Labem, where slope is composed as from natural materials so from man-made deposits, see Fig. 4. 6, e.g. Záleský, Bohadlová and Bubeníček (2005); Záleský 2011. They used different methods for monitoring, but pore water measurement and slope deformation with inclinometers played there more important role. But also different geodetic methods were applied, Raška and Pospíšil, 2011; Ratiborský, 2011; Pospíšil et al, 2007. Monitoring approved slope instability and with the help of inclinometers – see Fig. 4.7 - it was possible to determine the depth of slip surface. Later on some protective measures were proposed, as pile retaining wall and again the monitoring was applied on pile armature, Fig. 4.8.

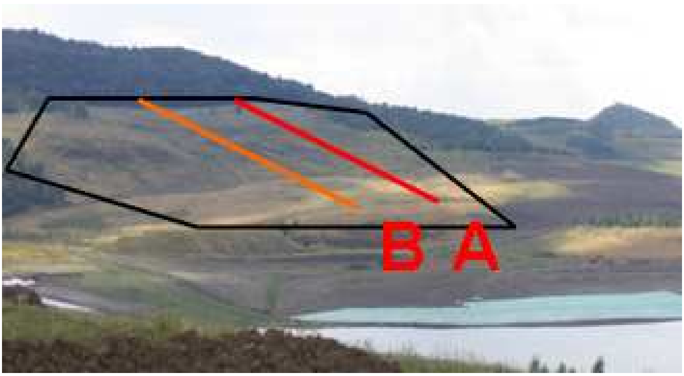


Figure 4.6: Overall view on the Rabenov area where slope movement were monitored, Záleský.

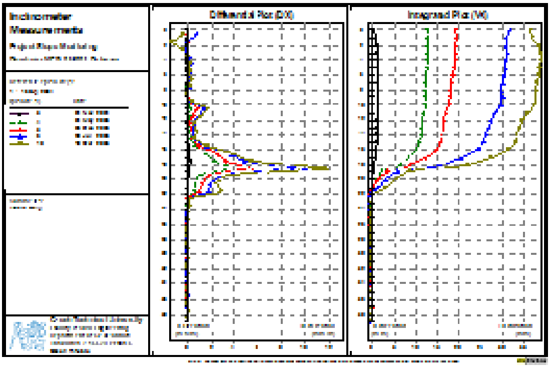


Figure 4.7. Results of the inclinometer measurement.

Figure 4.8: Pile armature supplemented by monitoring system.

4.2.1.3 Spoil heap long term stability

Slope stability of clayey fill calculation for spoil heaps is more complicated than for classically compacted fill due to following aspects, e.g. Vaníček and Chamra (2008):

- Extreme height of spoil heaps,
- Decrease of shear strength as a result of moisture content increase,
- Possibility of development of local zones with significantly decreased strength.

In eighties of the last century 4 large landslides of spoil heaps occurred in north part of Bohemia each with volume of moving mass exceeding 50 mil. m^3. Velocity of mass movement was maximally few meters per day. Therefore it was possible to stop the movement in one case by huge loading berm with volume of 0.75 mil. m^3 composed from coarse material at the moment when central part of landslide was in average inclination 1:18.

Therefore the inclination can vary in extremely large range, from roughly 1:1 (1:2) for newly deposited clay clods if the total height is not exceeding 20 m up to above mentioned 1:18. Mildest inclination is associated with old slip surfaces in the spoil heap body, when the residual angle of internal friction φ'_r is about 6-8°. Effective angle of internal friction φ´ is most often in the range of 13-17°.

The progressive decrease of slope inclination is connected with landslides which can have either deep slip surfaces or shallow ones. To decrease the possibility of slip failures occurrence it is now recommended constructing spoil heaps with general inclination roughly 1:6, where steeper lower slopes are combined with benches.

The slope stability during filling can be performed by two basic approaches:

- to use total parameters of shear strength (c_u, s_u),
- to use effective parameters of shear strength {φ' (φ_{ef}), c'(c_{ef})} and to control the pore pressure development inside of spoil heap body.

In the first case undrained shear strength can be estimated with the help of penetrometers tests – scatter is however very large but on the other side probabilistic approach can be used. Nevertheless the discussion is about the correlation between results of penetration tests and undrained shear strength especially for unsaturated zones.

In the second case the biggest problem is connected with pore pressure measurement or with its estimation. During the last period pore pressure measurement is not the exception, using not only classical piezometers, but also special measuring devices described e.g. by Feda et al (1994). The observation proved that first signals about positive pore pressure starts at depth h_i at which macro-pores are closed. Further increase is nearly linear, so that the pore water pressure can be expressed by equation:

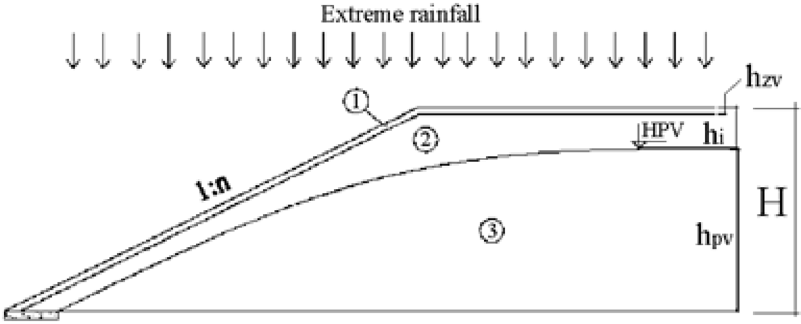
$$u = C \cdot \gamma_{fill} (h - h_i)$$

where *h* is depth below surface;

C – coefficient of pore pressure, varying from 0 to 1.0 for fully saturated parts of the spoil heap. Average values C = 0.5 – 0.7. With the help of this approach the speed of filling can be checked to prevent slope failure development.

For long term stability the phreatic line is still going up ending roughly at the depth of h_i,. The influence of heavy rainfall was observed many times and some correlation between rain-fall and number of slope instability was observed. This relation was very sensitive during heavy rainfall in 2002, the period which is also connected with heavy floods. For heavy rainfall it is supposed that the upper part is fully saturated, as bottom part, under ground water table, Fig. 4.9. Between is partly saturated layer with interconnected air pores where air pore pressure is higher than pore water pressure.

Stability was calculated by software GEO5, using conventional methods of slope stability. For slope with height H = 100 m, inclination 1:6 and soil shear strength parameters: φ´ = 15°, c´= 10 kPa, the factor of safety was F = 1.27.



① Upper layer saturated by rainfall
② Layer with interconnected air pores – $u_a > u_w$
③ Fully saturated layer, C = 1.0

Figure 4.9: Modelled layers distribution for long term stability

4.2.1.4 Conclusions

Spoil heaps composed from the excavated tertiary clays which overlay brown coal are new artificial earth structures strongly influencing our landscape. Regarding the necessity to use the surface of these spoil heaps for new construction the long term slope stability is a primordial question. Clayey clods are untypical material, the character of which is changing from one side of the soil mechanics spectrum (rockfill) to the second one (soft clay). Therefore the technology of filling, construction of the drainage layer at the bottom of spoil heap and measures to prevent development of the local slip surfaces, along which the shear strength can fall down to the residual strength, are so important. The recommendation is to construct the spoil heaps with general inclination roughly in the range of 1:6 – 1:7 to prevent development of these local slip surfaces. This inclination after that was controlled for long term stability taking into account also extreme rainfall. For this case we assumed that intermediate layer which was up to now partly saturated is closed between two layers which are fully saturated and therefore the air pore pressure inside of this layer is directed by pore water pressure of the upper layer and is therefore increasing pore water pressure in the lower layer. Probability of shallow slip failure is also high but the potential risk of this fact is not so sensitive from the construction on the surface of spoil heap point of view. Partly this risk can be eliminated by revegetation of spoil heap surface.

4.2.1.5 Stability of landfills

Old chemical landfill Chabařovice is situated close to the town Ústí nad Labem along the road connecting Ústí nad Labem with small town Chabařovice. Storing of the waste material started roughly 100 years ago. Originally landfill was used for storage of slag and ash from chemical, glass and textile industries. Later on different chemical waste materials were stored there as different sludge from the production of organic pigments, from production of caustic lye by mercury electrolysis, from production of potash, arsenic sludge and many others. In the southwest part barrels with hexachlorbenzene were stored. Barrels were covered by acid gypsum containing 2-3 % of sulphur acid. Landfill was also used for storing different waste material from industrial accidents. Detailed information is unknown about all the stored materials during the lifetime of this landfill.

A basic assumption of the landfill remediation is based on the principle that no material will be transported out of the landfill area. Therefore the individual steps of the remediation process are as follow, Vaníček et al (2003, 2005):

- Ground reshaping,
- Measures for drainage of surface water as well as for internal contaminated water,
- Vertical sealing system all around landfill,
- Measures against dusting and combustion processes inside of landfill body,
- Measures to increase slope stability of the landfill body,
- To protect infiltration into landfill body by horizontal sealing system,
- Recultivation of remediated surface and surrounding landscape,
- Monitoring remediation actions.

All protected area inside fencing is roughly 40.8 ha with 26.8 ha surrounded by vertical sealing wall. Top of the landfill is the highest place with slopes all around. Close to this peak was small lagoon where liquid waste material was stored, Fig. 4.10.

Figure 4.10: Chabařovice landfill. Aerial view during remediation.

The body of the landfill was not stable in the history, different movements were observed, very often connected with small – creep – movement, and it was very sensitive to the rainfall. Landfill reshaping has to guarantee not only that the surface sealing system will be gravitationally drained but also that the lower general slope inclination will increase slope stability. Additionally the loading berm was proposed and constructed in the north-east part of landfill, where previous instability was observed. But in fact first problems started during the excavation for loading berm when local slips occurred. In summer 2001 the sealing wall was finished as well as the capping system in the central part of the landfill. After heavy rainfalls in September 2001 first cracks were observed in the north-east part of the landfill, roughly in the middle of the slope, where ground shaping was not fully finished yet.

The reason why the cracks were observed in the middle of the slope was not so difficult to explain due to an injection of the upper part where barrels with liquid waste material were expected and also due to higher infiltration of the surface water from the upper part, where capping system was finished. Visual and geodetic observation proved lower speed of deformation in the autumn and winter time, but after another speed increase 7 inclinometers were installed in March 2002. They proved shear movement in depth of about 20 m in inclinometers just below observed cracks, about 5-7 m just front of the sealing wall and no deformation behind sealing wall. Cross section is shown in Fig. 4.11. From the beginning the main discussion was associated with character of slope instability, because especially in IJ 5 shear deformation was only in the order of mm per month. Results from inclinometers IJ4 and IJ5 (and similar ones in the second cross section) were indicating slip surface, but on the other hand in the lower part no indication of surface uplift was observed to balance the mass lost in the upper part. To check the influence of creep deformation on the slurry wall, the surface was cleaned (protected during winter time) and only small cracks (1-3 mm) were observed, perpendicular to the longitudinal axis of the wall and guiding concrete strips. Shearing along these cracks reached max. 10 mm. Therefore the outer face of the vertical sealing wall was exposed and cracks were observed there, partly filled by clay. Width of these cracks was higher than on the surface, therefore the discussion of the width of the pit to allow bending loading of the exposed wall started. After that the discussion if the slope deformations are due to slip shearing, or as the results of continuous deformation of the deposited clay, or as the result of collapse of spaces after old deep mining activity (roughly 20 m under surface of tertiary clays), was not so important.

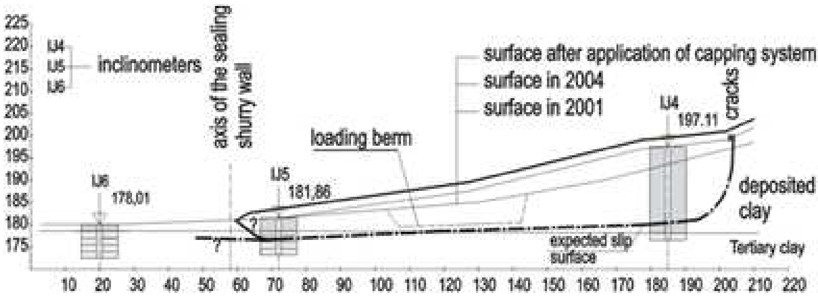


Figure 4.11: Section through reclaimed Chabařovice landfill

At this stage it was doubtless that some additional steps should be taken and that the price of the remediation will go up. The problem was that so many construction process participants started with some initiative – designer, investor, contractor, supervisor etc. Field investigation included another inclinometers (result of which was that the slip surface can be even deeper in the lower part, but shear deformations were again very low there), and pore pressure measurement. Pore water pressure was very high, exceptionally even higher than the surface at this time, probably as the result of the additional loading in this part, indicating that the pore pressure parameter B is close to 1.

Many different slope stability calculations were executed, as methods of limit equilibrium so FEM. For average inclination between inclinometers IJ5 and IJ4 roughly 8° and residual angle of the internal friction roughly 11.5° it is obvious that pore pressure plays most significant role. Potential slip surface is situated close to the boundary of origin tertiary clays with new deposited clays, where lowest shear strength can be expected as the result of water inflow and kneading in newly deposited clay and due to upheaval and swelling at the surface of origin tertiary clay. When using wedge method of calculation it was concluded, that the potential slip surface will go up in the lower part close to the axis of the sealing wall. Therefore when discussion what method of stabilization of slope deformation have to be used the method of lowering pore pressure by vertical drains supplemented with small additional loading berm was preferred front of the methods proposing retaining wall from deep piles.

Still the investor preferred to prove the proposed method on limited area. Therefore at the end of 2003 vertical geodrains were installed on selected area – roughly 30 000 m with average depth about 12 m (between 7-17 m). Proposed depth 17 m was reached only in the exceptional case because the resistance was bigger than expected from the penetration tests. Results of the pore pressure measurement proved quick pore pressure dissipation and the same result was obtained when additional loading berm was applied above area with vertical drains.

Final recommendations therefore include the following steps:

- To realize another vertical drains in strip above sealing wall (roughly 80 000 m with average depth 15 m),
- To add loading berm above this part,
- To add additional thin vertical sealing wall below existing one,
- To substitute proposed compacted clay liner (CCL) on the surface by bentonite mattress (GCL) to decrease additional loading and to improve the flexibility of the surface sealing.

4.2.1.6 Rock falls

From the stability of slopes point of view very sensitive is problem of rock falls. Even the Czech Republic is not extremely mountainous country; many problems are situated along deep river valleys where between river (or reservoir) and adjoining rocky slopes are situated transport infrastructures – motorways, railways. Typical example is road between Prague and Štěchovice, especially close to the Vrané reservoir on river Vltava. Dam and road were constructed in 30-ties of the last century and from these days there are many accidents, when falling rock is affecting transport on the road, Jirásko, Hrubý and Vaníček, 2011. One of the main reasons of instability is dip of discontinuities, which are roughly parallel with slope surface, Fig. 4.12; 4.13.

Figure 4.12: View on the rock slope, road and reservoir close to Vrané.

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Figure 4.13: Potentially dangerous blocks

Therefore all area was overlooked and on the map the most critical spots were marked out, e.g. Fig. 4.14.

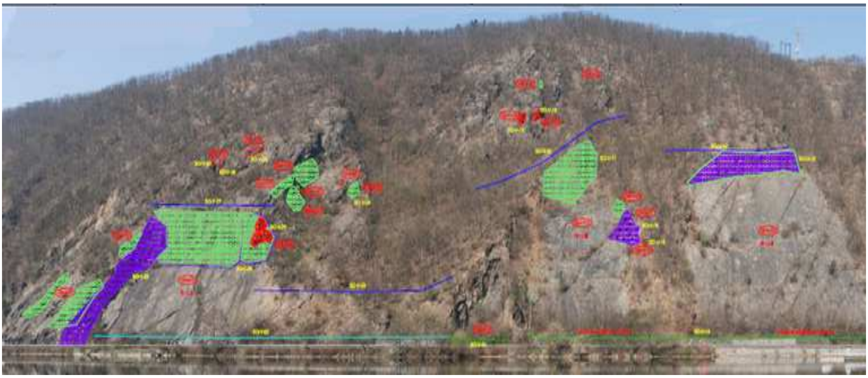

Figure 4.14: Slope with recommended protection measures

After that different steps were proposed for elimination of potential danger, Vaníček et al. (2009):

- Retaining walls – especially in places with a certain accumulative space for falling rock particles – where the slope toe is ending with a certain distance from the boundary of road. On that occasion new retaining walls utilizing old waste tyres were proposed, see Fig. 4.15, which are able to decrease the energy of fall.
- Retaining panel – composed from steel fixed beam between which are above ground fixed beam wooden sheeting planks;
- Detaining nets covering slope surface and fixed by anchors– limiting rock particles movement;
- Dynamic barriers – able to catch falling rock particles with elimination of their energy of fall;
- Disintegration of rock blocks up to size 5-10 m^3 which have very high potential of instability;
- Monitoring of the rock block, with wireless transfer of monitored data and connected with warning system enabling transport closure.

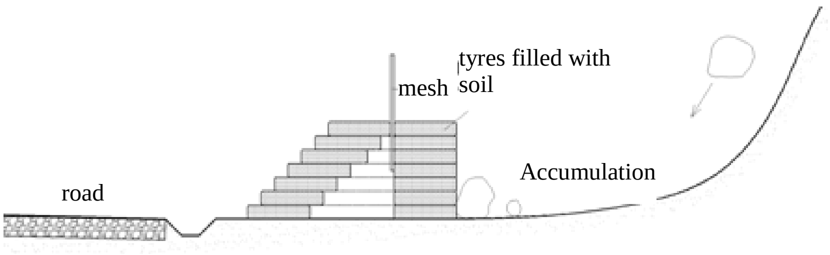

Figure 4.15: Protection barrier –reinforced earth structures utilizing old tyres.

4.2.2 *Floods*

During last two decades floods caused many problems in the Czech Republic. Therefore more attention is devoted to this problem, either with respect to their frequency, to protection with help of different flood protection measures. During last period the emphasis is superimposed on information system, how some problems on dikes can be recognized, how to behave during floods, what actions can be useful, etc.

In the Czech Republic there are roughly 3 different types of floods:

- Regional – affecting 1 or more river-basins, coming usually in summer and is caused by long term heavy rainfall;
- Local – affecting small area – caused by extremely high local rainfall (storm) – most difficult from the forecast point of view;
- Floods in foothills – during spring, when the soil is still frozen – caused by combination of snow melting and rain.

Very often during last period we are speaking about frequency of floods, as for example in the Czech Republic different floods were recorded, especially the regional ones in 1997,1998, 2002,(see Fig. 4.16 showing the situation in Prague during heavy floods in 2002) 2006, 2010.

However from Fig. 4.17 showing floods in Prague during the period of 1825 -2002 it is clear that the flood in 2002 was strongest during last 2 centuries; however flood frequency during last decade of the last century was also exceptional. The 2002 flood also heavily affected the Prague metro system, Chamra, 2009.

Figure 4.16: View on Vltava river in Prague during heavy floods in 2002 (August 14, August 22).

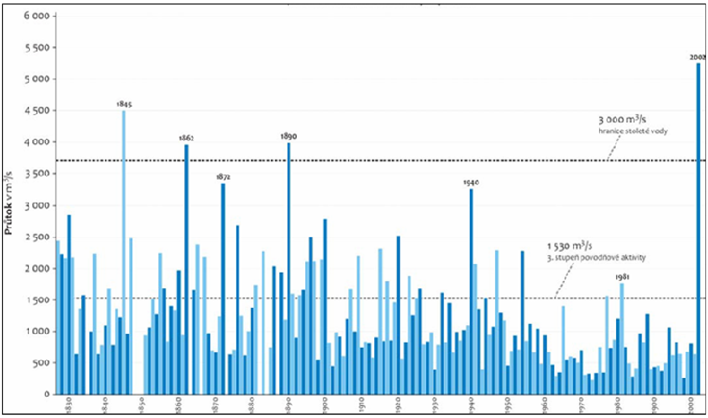

Figure 4.17: Prague - floods during the period of 1825 -2002

Specificity of the flood in 2002 was caused by heavy rainfalls which had 2 peaks very close to each other. Nearly all country was affected with maximum in south part of the country. Since all rivers in Bohemia are flowing north direction – reaching boundary with Germany close to Dresden, practically all country was strongly affected by this flood.

Fig. 4.18 is showing water level above "normal" level in rivers Malse and Vltava in south part of Bohemia. After first peak – roughly August 7th – 9th subsoil was fully saturated with nearly zero additional adsorption capacity. So when new rain started on August 12th practically all water flow out to the rivers, causing raised water there.

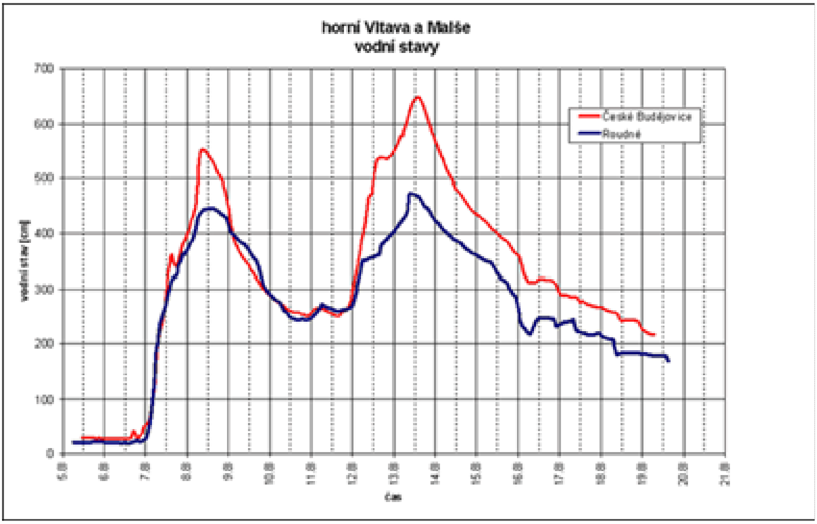

Figure 4.18. Water level above "normal" for rivers Malse and Vltava in south Bohemia in summer 2002.

4.2.2.1 The impact of floods on old earth-fill dams

Roughly between 300 up to 600 years ago many small earth dams were constructed mainly in the south part of the Czech Republic. They were used mostly for fish production and flood protection. To present day roughly one third survived, leaving the number close to 25 000. Dam crest height is between 3 and 15 meters and these earth-fill dams were constructed as nearly homogeneous dams from the local soils.

During catastrophic floods in 2002 many of these 25 000 dams had some problems but less than 0.3% failed. The highest concentration of failures were connected with small river Lomnice, Fig. 4.19, situated roughly 100 km south of the capital Prague, where 5 dams failed and 2 others were damaged, mostly by the so called domino effect, Vaníček I and Vaníček J (2004). The reasons and manners for dam failure are discussed together with a new approach for the overall stability. Also some practical results from reconstruction are added.

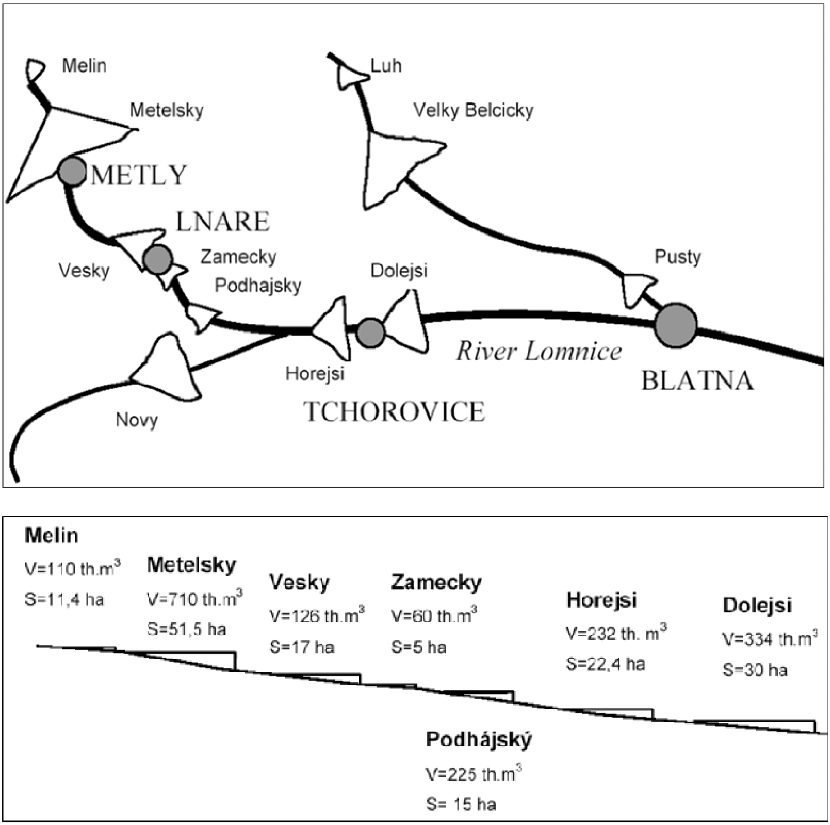

Figure 4.19: Little river Lomnice – Situation and scheme of dams.

Heavy rainfalls during 7 and 9th August 2002 did not cause any problems; pond reservoirs were nearly full and fulfilled their flood protection role. The situation was improved during Saturday and Sunday (10-11th August) and with the help of directed outlets a certain reservoir volume was prepared, for example in 3 cases water level was 0.3 – 0.6 m under normal level.

New heavy rainfalls started on Monday, which had very quick effect due to the full saturation of surrounding land. On Monday evening the flow volume reached 100 years flow rate. But still all dams were able to catch all these volumes.

The critical situation started at around 4 am of the next day when - due to overflowing - the first dam (Melín) on this river-basin failed. Additional wave reached the crest of the next dam "Metelský" in few minutes and very quickly this dam also failed in 2 places, Fig. 4.20.

Figure 4.20: Dam Metelský – gash with old wooden outlet

Relatively large volume from this reservoir (about 1 mil. m^3), with the estimated (and recalculated) outlet more than 500 $m^3.s^{-1}$ (which was much higher than 100 years flow rate – ca 20 $m^3.s^{-1}$), affected the villages Metly and Předmíř, where some houses failed and one man died. The embankment of the next pond "Veský" survived due to the very wide crest with asphalt pavement but was strongly eroded on the downstream side. The same situation was observed on the next pond "Zámecký", the crest of which is also protected by asphalt pavement – European road E 49 is passing through it. The embankment of the fifth pond (Podhajský) resisted for a few minutes, even when the water went over the crest (the calculated 100 years capacity of spillway was not sufficient), but finally also failed in the place where the reconstruction was realized roughly 13 years ago.

Flood wave after that reached the railway bridge which survived but the continuing embankment on both sides of the bridge was eroded, leaving railway track in the air, Fig. 4.21.

Figure 4.21: Eroded embankment of the railway track Nepomuk – Blatná

The last two dams also failed, when the leading one (Hořejší) strongly affected the village Tchořovice, Fig. 4.22. After the failure of the last one (Dolejší) the flood wave was getting flatter in much wider and flatter valley so that the impact on the town Blatná was diminished. But even there the damages were very high, because on the brook, joining Lomnice in Blatná, 3 dams (Luh, Velký Bělčický and Pustý) failed as well, Fig. 4.23.

Figure 4.22: Failure of dam Hořejší and impact on village

Figure 4.23: Town Blatná – On 13 August 2002 morning

4.2.2.2 Domino effect

Metelský pond, second pond on the Lomnice river basin, had higher storage capacity than the rest of following ponds bellow it. Therefore the flood wave from this pond had such a great negative impact on the safety of the ponds bellow it. Practically all failures started with time delay when this wave reached the individual pond, so it means that the ponds bellow have no chance to survive. The author this situation identified as domino effect, Vaníček I. (2004). During last period a great attention is devoted to this effect, as it can be very dangerous for many other river basins, e.g. Vaníček and Pecival (2011).

4.2.2.3 Limit state of surface erosion

In all observed cases the surface erosion played the most important role, but in two cases the internal erosion also probably participated in the final collapse. For example in one place of failure – gash – of the embankment of the pond Metly, the part of the old wooden outlet was found, see Fig. 4.19. From the historical records this old outlet was left there roughly in 17th century, because from these days a new place for new outlet was selected. Approximately, in this profile, on the downstream side the place with higher humectation (moisture content) was observed for last decades, probably as the result of higher permeability in this profile. Due to higher hydraulic gradient, the clogging of this old outlet failed and internal erosion started in this place.

Therefore the main attention is devoted to the protection against surface erosion due to overflowing. For long crest of the earth dam or for dikes the first step is connected with unification of the crest vertical alignment in all length, as surface overflowing starts in lowest point followed by erosion. The second step is coming out from the same principle, to select the place where overflowing below the dam (dike) can cause minimum problems and at this place to construct new additional spillway, the crest of which is few decimetres below of the main crest. This principle was proposed and realized during the reconstruction of small dams on Lomnice river however the crest of this additional spillway was reinforced. Firstly by concrete – see Fig. 4.24, however later on the principle utilizing the reinforced embankment (with layers of brick-fibres-concrete) was recommend after laboratory, field and numerical testing – see part 3.3.4 and Fig. 3.20. The advantage of such spillway is not only in the reduction of amount of water which will overflow the main crest, but also as first signal that the critical situation can start.

Figure 4.24: Additional spillway with lowered and reinforced crest

For shorter length of the crest the reinforcement can be applied for all length. Cheaper and environmentally friendlier is solution recommended for dry dam, the main aim of which is to decrease flood wave during floods. Bottom outlet has capacity enabling to pass through only inflow let say equal to Q_{10} – Q_{30}. For higher inflow the water is starting overflowing along all length of crest. In this case the entire crest was reinforced by anti erosion COLBOND geosynthetic mattress which was very well connected with subsoil, not only at the crest – see Fig. 4.25 – but also with the help of long pins to the downstream face of the dam. After seeding with grass the root system help to even improve this connection, Fig. 4.26. Practical experience with this case - two times overflowing with no damage - showed that this solution is also very good.

Figure 4.25: Geosynthetic mattress anchoring at the dam crest

Figure 4.26: Downstream face after grass revegetation

4.2.2.4 Maps of the flood risk and potential damage

From the view of risk management the following conditions have to be known:

- What is the area affected by flood – and the estimation is performed more often for Q_{100}, even at the beginning of this chapter also higher protection was mentioned; therefore for solved region numerical models are used which were verified by reality (experience from real floods) – see Fig. 4.27.

- What is the potential damage to the elements at risk; what damage (expressed in finance unit) can be caused in the area affected by this flood;
- What financial capital will be needed for improvement of flood protection system;

For evaluation of the effectiveness of anti flood measures Fošumpaur, 2005; Fošumpaur and Satrapa, 2011 prepared methodology for this evaluation which is now used by Ministry of Agriculture which is financing anti flood measures.

Figure 4.27: Model of area affected by flood and potential risk which can be caused there

4.2.3 *Earthquakes – (explosion, other dynamic impacts)*

Problem of earthquakes is very sensitive in many countries over the world; however the geological conditions of the Czech Republic are rather insensitive to this phenomenon. Nevertheless maps of expected sensitivity to the earthquake of a certain degree are published and from them the area close to the western boundary with Germany (close to town Cheb) is most sensitive. Maximum expected earthquake can cause only limited damages to buildings, to infrastructure. Sensitive to the earthquake is also subsoil, especially in cases when fine non cohesive soils are there in loose state. Even worse is situation when these fine sands are fully saturated, as the earthquake can cause liquefaction of such fine sands with significant deformation of subsoil. Therefore the care should be devoted to backfilling of excavations of different pipes.

For very sensitive structures with extremely high risk to the surrounding environment such as nuclear power plants, it must be proved that with high probability (about 10^{-6} – 10^{-7}) the structure can not be affected by earthquake up to a certain limit (4-5 degree on the scale), if no measures have to accounted for – as is the case of the Czech Republic. It is usually performed during EIA (Environmental Impact Assessment) process. For such probability study it is necessary to use also historical data, in some cases the impact of strong earthquakes occurring out of country, e.g. in middle ages in Italy.

In countries with expected higher degree special measures have to be used during design and construction of such nuclear power stations. But in these countries some special measures should be applied also for other structures and after that earthquake impact on building, infrastructure and of course on lives can be significantly limited. Towhata (2008) summarize typical geotechnical problems associated with earthquake. New types of structures can be also proposed, based on the experiences from field observation. One of such examples are reinforced retaining walls, where horizontal geosynthetic reinforcement can help very much, see Fig. 4.28. 4.29, Koseki (2010), Vaníček (2010).

Figure 4.28: Kobe 1995 – Impact of earthquake on motorway

Figure 4.29: Kobe 1995 – M_w = 6.9, Reinforced retaining wall compared to other structures.

Experiences obtained in situ for structures behaviour can be very useful for many other cases where structures are affected by dynamic loading –as by different machines, e.g. by turbine-generator unit or just by compacting machines, vibratory rollers, Máca and Pohl, 2005; Pohl, 2008. However we cannot forget also on theoretical terrorist attack. A great attention was therefore devoted to explosions, e.g. Foglar and Karasová, 2008; Foglar, Karasová and Křístek, 2009; Karasová and Foglar, 2009; Foglar et al., 2011.

4.2.4 *Fires*

Fires can be caused either by natural hazards (e.g. by thunderbolt) or by man- made accidents. For construction sector this problem is very sensitive. Especially for two cases:

- For buildings with light skeleton system, as timber skeleton or aluminium one. For timer skeleton it is one of the basic conditions for higher application of these structures on our domestic market.
- For tunnels as the result of traffic accidents – the impact on quality of lining is usually smaller than on the human beings which are inside of tunnel at the moment of fire.

The second case is mostly solved via new rules and conditions defined by fire brigade. For first case different approaches are used:

- Experimental models on which reality and numerical models are verified
- Numerical models which are used for checking whether the defined conditions can be fulfilled by proposed structure.

Wald with his team realized experimental models in the scale 1:1 for defined conditions – see fig. 4.30 – 4.32. and via different monitoring systems (via temperature, deformation) they have now possibility to verify different numerical models, e.g. Wald et al., 2008; Wald et al., 2011.

Figure 4.30: Experimental station – Mokrsko

Figure 4.31: Initial phase of the test

Figure 4.32: Model test – scale 1:1 – timber roof

4.2.5 *Traffic accidents and ecological calamities*

Traffic accidents and ecological calamities each form independent group of problems, therefore they will be described firstly separately and later on together, as synergic effect is extremely important especially for future.

In the frame of the research project the attention was devoted either to the theory, so to the practical problems. For transport engineering theoretical problems are connected e.g. with regression analysis of accidents on cross-roads, Hála, 2005, or with forecast of density of traffic, Hála, 2011. Slabý, 2011 is using numerical modelling to increase the roundabout capacity for 20and 50 % of cars. With the help of statistical evaluation of transport accidents and also with the help of own investigation in micro scale, maps of density of traffic accidents were presented and subsequently utilized, Slabý, 2009. On most sensitive places new roundabout junction was proposed, as well new system of traffic sign, e.g. for city Liberec.

A great attention was devoted to the sensitive problem of the car collision with animals, as new transport communications are crossing traditional paths of these animals. We are speaking about eco-ducts; where they have to be constructed and what construction system is most appropriate for a certain case, Foglar and Křístek, 2005, 2009.

Old ecological burdens were partly solved in the first phase of the research project and also now in connection with problem of construction on brownfields, see chapter 1. How the remediation of old contaminated subsoil is sensitive in the Czech Republic is obvious from the fact how long the government is preparing selection procedure and bidding for remediation of most of the remaining ecological burdens. Total sum for all problems they should fall under this super bidding is little bit higher than 4 000 mil. EUR.

Therefore our attention was also devoted to the combination of traffic and ecological accidents in connection with possibility of accidents of transportation vehicles carrying different chemicals. In connection with this problem our attention is concentrated on two basic problems:

- Sealing system below railway track and highway pavements;
- Contaminant spreading – speed of spreading, sorption capacity to be able very quickly defined the zone of subsoil which was affected by leakage from the crashed vehicles – especially from the view when contaminant can reach ground water table – and what remediation methods can be used for each specific case.

First problem is not only connected with traffic accident but also with more general problem. In order to protect our environment from the spills on the transport infrastructure embankments, it is necessary to collect the surface run-off water into collection ponds, where water will be temporarily stored and cleaned if necessary, e.g. Vaníček and Vaníček (2008). For fulfilling both mentioned tasks sealing system utilizing geomembranes or other sealing layers as bentonite mattresses under all area is proposed and combined with drainage system which drains contaminated liquid to the collection pond. Fig. 4.33 shows installation of bentonite mattresses – called also as GCL – geosynthetic clay liner to protect environment from spillage from railway and Fig. 4. 34 is a photo of settling pond near motorway during construction.

Figure 4.33: Photo of GCL installation on slopes of railway embankment to protect environment from spillage.

Figure 4.34: Photo of settling pond construction close to motorway.

For solution of the second problem – contaminant spreading, beyond classical case (homogeneous environment fully saturated) also two others cases were studied:

- Unsaturated environment;
- Seepage with preferential paths, as subsoil is not homogeneous environment, it is environment where different preferential paths along which seepage is going much faster are –see e.g. Zumr and Císlerová, 2008; Císlerová et al., 2011.

5 CONCLUSION

Presented report is written in the form of the State of the Art Report as is giving general overview of problems falling under the term of Sustainable Construction. Report comes out from the author own experience obtained from directing the research project of the same name supported by Ministry of Education of the Czech Republic. Report also shows how wide problems are covered by this term and how much the solution of this problem at present time and also in the future can help for the fulfilment of the basic principles of Sustainable Development in Civil and Building Engineering.

Last note can be added to the economic view, as sustainable solution should be also economically acceptable. Therefore also economical aspects were in the centre of interest, as economical risk factors of sustainable construction – Klvaňa, 2006. By Klvaňa also 3 volumes of the reference manual of risk analysis were published.

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Enhanced Geotechnics and Geothermics for sustainable construction

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1 INTRODUCTION

For sustainable construction an economic and environment-friendly design is necessary (Vaníček 2007). The World Commission on Environment and Development defined sustainability as follows: "Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987). A scheme of the main constituent parts of sustainable development is shown in figure 1.

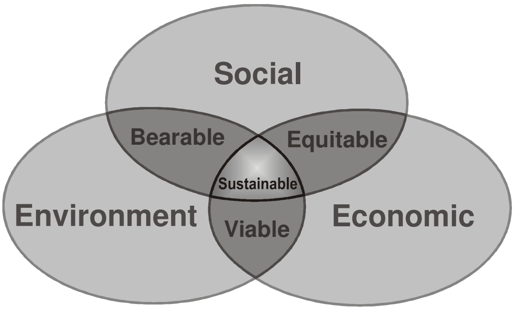

Figure 1. Scheme of sustainable development.

By means of an enhanced geotechnical and geothermal design of foundations the construction material used, construction time spend and energy consumed can be reduced within the buildings construction and service time (Katzenbach et al. 2010b, 2010c). This contribution describes four different elements for an enhanced design of foundation constructions.

The Combined Pile-Raft Foundation (CPRF) is a reliable and cost-effective deep foundation system. The design concept of the CPRF is based on advanced calculation methods and on the monitoring of the foundation performance within the concept of the observational method. The CPRF has been successfully used for many high-rise building projects and the foundation of bridge piers.

The optimised design of deep foundation systems relies on the knowledge of shaft and base resistance values, which should be obtained from load tests.

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The urgent need of reducing CO_2 emissions promotes the worldwide search for environmental friendly and resource friendly regenerative energies. Geothermal energy – the thermal use of the subsoil and the groundwater – is a promising alternative to conventional energy sources. Various technical solutions for the thermal use of the subsoil such as borehole heat exchangers, energy piles and others are available and can be used in combination with classic pile foundations and with the CPRF. By use of thermally activated deep foundation elements the fossil energy consumption of a building can be reduced significantly in it service time.

The reuse of existing foundations is gaining importance if structures are refurbished or rebuilt. This approach offers economic and environment-friendly advantages compared to the installation of new foundations. In order to guarantee safety and serviceability of reused foundation elements a careful assessment has to be done (Ulitsky 2003).

2 COMBINED PILE-RAFT FOUNDATION (CPRF)

2.1 Design concept of a Combined Pile-Raft Foundation (CPRF)

Designing CPRFs requires the qualified understanding of the soil-structure interaction (figure 2) (Randolph et al. 1993, Poulos 2001, Hanisch et al. 2002). According to its stiffness the CPRF transfers the total vertical load of the structure $R_{tot,k}$ into the subsoil by contact pressure of the raft $R_{raft,k}$ as well as by the piles $\Sigma R_{pile,i,k}$ (equation 1).

$$R_{tot,k}(s) = \Sigma R_{pile,i,k}(s) + R_{raft,k}(s) \tag{1}$$

In equation 1 $\Sigma R_{pile,i,k}$ is the sum of the base and shaft resistances of the piles (equation 2) and $R_{raft,k}$ is the resistance of the raft (equation 3).

$$R_{pile,i,k}(s) = \Sigma R_{b,i,k}(s) + R_{s,i,k}(s) \tag{2}$$

$$R_{raft,k}(s) = \iint \sigma(s,x,y)\,dx\,dy \tag{3}$$

In comparison with a conventional foundation design of a pile group for CPRFs a design philosophy is applied which takes into account the complex soil-structure interaction effects. Piles are used up to a load level which is much higher than permissible design values for bearing capacities of comparable single piles because the performance of the entire structure is evaluated.

The distribution of the total building load between the different bearing structures of a CPRF is described by the CPRF coefficient α_{CPRF} (equation 4) which defines the ratio between the amount of load carried by the piles $\Sigma R_{pile,i,k}$ and the total load of the building $R_{tot,k}$.

$$\alpha_{CPRF} = \frac{\Sigma R_{pile,i,k}(s)}{R_{tot,k}(s)} \tag{4}$$

A CPRF coefficient of zero describes a raft foundation without piles, a coefficient of one represents a classic pile group, neglecting the existence of a raft. Positive effects of the CPRF are:

- reduction of settlements, differential settlements and tilts,
- increase of the overall stability of the foundation,
- reduction of the bending stress for the foundation raft and
- cost-optimisation of the whole foundation.

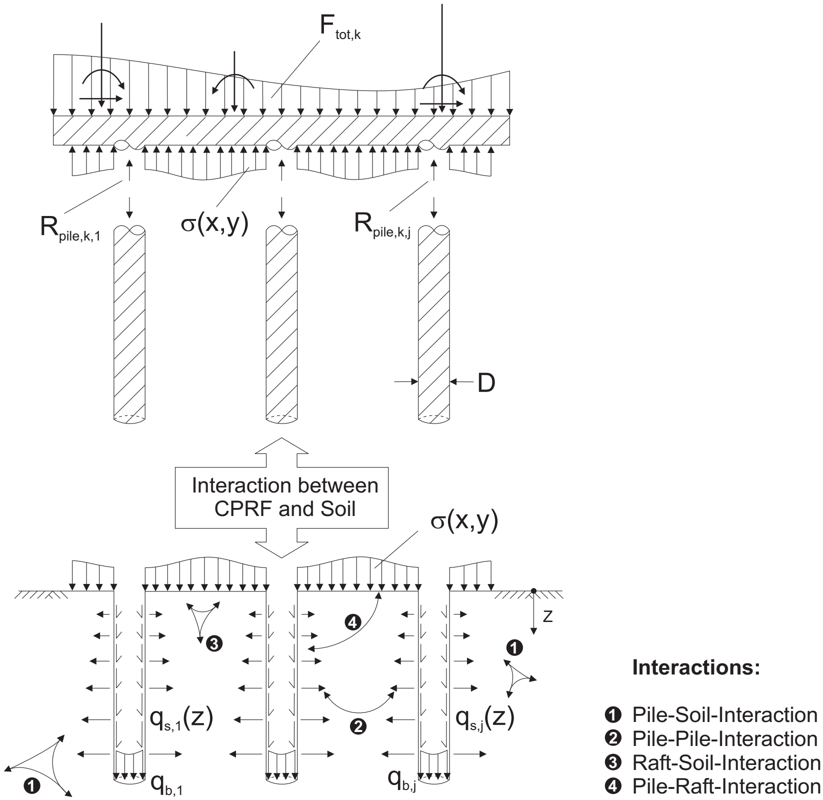

Figure 2. Soil-structure interaction of a CPRF.

In order to asses the load-settlement behaviour and to calculate the internal forces of a CPRF realistically three-dimensional finite element simulations are usually required (figure 3). These simulations allow the consideration of complicated geometric shapes and take into account all relevant interaction effects. They provide a valuable tool to perform simulations with different pile configurations in order to optimise the foundation structure.

A constitutive model used for simulations should provide a reasonable good simulation of the stress-strain behaviour of soils, which depends on the stress path and the previous stress history. The material behaviour of the piles and the raft are simulated as linear-elastic in the finite element analysis. The subsoil should be modelled with an appropriate constitutive law, in most cases an elasto-plastic approach is required.

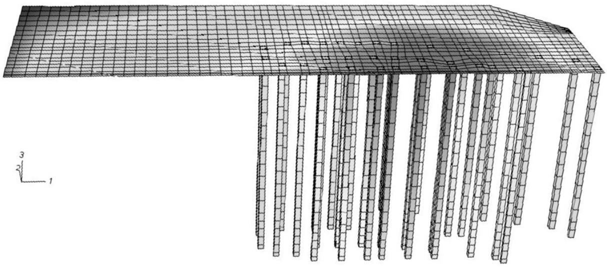

Figure 3. Exemplary finite element model of a CPRF.

The transition from pile to soil is modelled as ideal contact, assuming that shear failure takes place in a narrow zone adjacent to the pile which has the same material parameters as the surrounding soil.

2.2 Observational method

The bearing behaviour and the load transfer within a CPRF have to be monitored due to the requirements deriving from the soil, the superstructure and the foundation according to the concept of the observational method on the basis of the monitoring program set up in the design phase. The monitoring comprises geotechnical and geodetic measurements at the new construction and also at the adjacent buildings (Vaníček 2008, Katzenbach et al. 2010a). The principle of the observational method is explained in Eurocode 7 “Geotechnical design – Part 1: General Rules” and the German National Standard DIN 1054:2005 “Subsoil – Verification of the safety of soil engineering and foundations” and is shown in figure 4.

The monitoring of a CPRF is an elementary and indispensable component of the safety concept. It is used for the following purposes:

- verification of the computational model and the computational approaches,
- in-time detection of possible critical states,
- examination of the calculated settlements during the whole construction process and
- the quality assurance respectively the conservation of evidence.

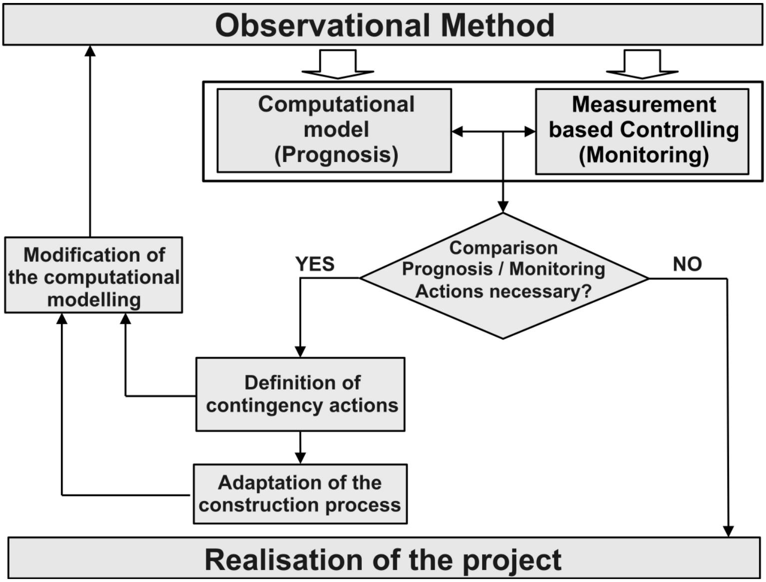

Figure 4. Principle of the observational method.

In the following the application of the observational method is explained by an example from engineering practice. The “Main Tower” is a high-rise building of 198 m with 5 basement levels and 57 levels above ground (figure 5). The total load of the building is 1,900 MN. The raft with its thickness of 3.0 m to 3.8 m is founded 21 m below street level and 14 m below ground water level. The building shaft is arranged asymmetrically on the raft. The design of the foundation was determined by the requirement to reduce the settlements of the tower itself and of the surrounding buildings in order to ensure their serviceability (Katzenbach et al. 1999, Moormann 2002). The “Main Tower” is founded on a CPRF including the raft and 112 large bored cast in-situ piles with a diameter of 1.5 m and a length of 30.0 m. The pile load is transferred in the Frankfurt Clay as the pile toes are located about 3 m to 8 m above the Frankfurt Limestone.

The project was controlled by geotechnical and geodetic measurements to observe the soil-structure interaction of the CPRF (figure 6). Aim of the measurements carried out in the foundation piles was the monitoring of their bearing behaviour as a pile foundation during the top-down method and later on as part of the CPRF. For this purpose 17 piles were equipped with load cells at the pile toe and 14 piles with load cells at the pile head. To determine the load distribution along the pile shaft 335 strain gauges were installed in 21 piles. The measurement data is automatically linked by a network to central units offering the possibility to assess and visualise the data.

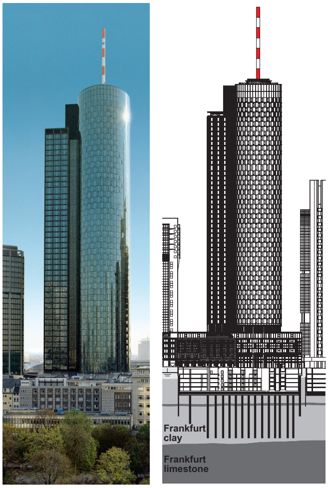

Figure 5. “Main Tower” building.

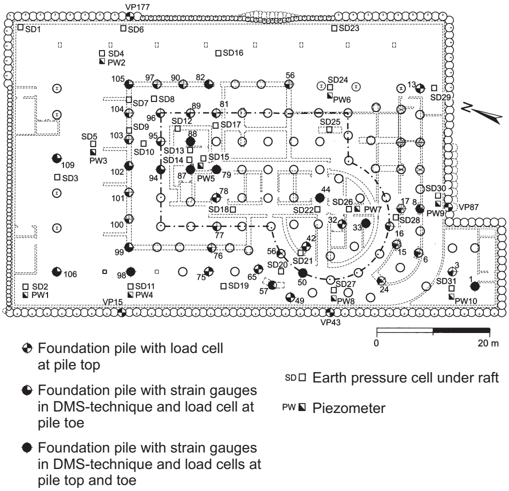

Figure 6. Instrumentation of CPRF.

3 LOAD TEST

3.1 Load test for estimation of subsoil-structure interaction

The soil parameters are determined based on projects- and site-related soil investigation with core drilling and laboratory tests. Those tests are important and essential for the initial definition of soil mechanical properties, but usually not sufficient for an entire and realistic capture of the complex conditions, caused by the interaction of subsoil and construction (Holzhäuser 1998, Katzenbach 2005). Therefore further investigations, foremost field tests, are required (DGGT 1998, Flemming et al. 1986, Ilyichev et al. 2001, Katzenbach et al. 2008a, 2009a, 2009b).

In order to reliably determine the ultimate bearing capacity of piles, load tests need to be carried out. In general, static load tests of piles in rock require very high loads. In many cases the rocky layers are covered by loose rock material, which is not foreseen for the load transfer and therefore should not influence the test results. Due to these boundary conditions conventional load tests can hardly fulfil the requirements. By using Osterberg method high loads can be reached without installing anchors or counter weights. Hydraulic jacks induce the load in the pile using the pile itself partly as abutment (Katzenbach et al. 2008b). For the design of deep foundations the results of field tests allow a calibration of numerical simulations.

3.2 Load tests in engineering practice

In the center of Frankfurt am Main, Germany, on a construction site of 17,400 m^2 the high-rise building project “PalaisQuartier” has been realised. The construction was finished in 2009. It is located next to one of the most frequented shopping streets in Germany, the “Zeil” (Janke et al. 2006). The project is illustrated in figure 7.

The complex consists of several structures with a total of 180,000 m^2 floor space, thereof 60,000 m^2 underground. The project includes the historic building “Thurn- und Taxis-Palais” whose façade will be preserved (Unit A). The office building (Unit B), which is the highest building of the project with a height of 136 m has 34 floors each with a floor space of 1,340 m^2. The hotel building (Unit C) reaches a height of 99 m with 24 upper floors. The retail area (Unit D) runs along the total length of the eastern part of the construction site and consists of eight upper floors with a total height of 43 m. The underground parking garage with five floors spans across the complete construction area. With an 8 m high first sublevel, partially with mezzanine floor, and four more sublevels the foundation depth results to 22 m below ground level. Thereby excavation bottom is at 80 m above sea level (msl).

A total of 302 foundation piles (diameter up to 1.86 m, length up to 27 m) reach down to depths of 53.2 m to 70.1 m above sea level depending on the structural requirements. The pile head of the 543 retaining wall piles (diameter 1.5 m, length up to 38 m) is between 94.1 m and 99.6 m above sea level, the pile base is between 59.8 m and 73.4 m above sea level depending on the structural requirements. As shown in the sectional view (figure 7), the upper part of the piles is in the Frankfurt Clay and the lower part of the piles is set in the rocky Frankfurt Limestone layers.

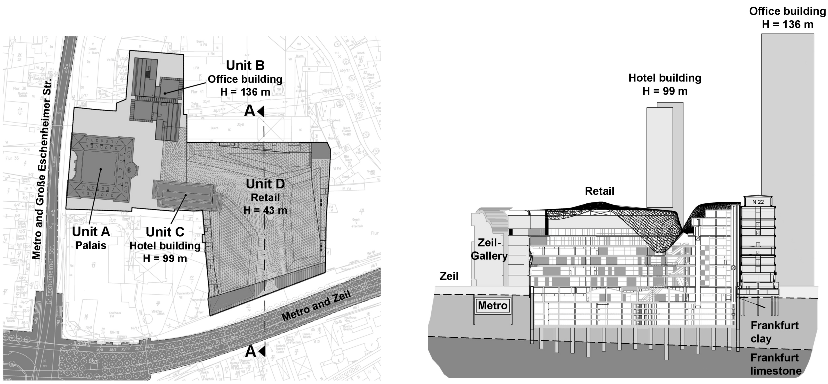

Figure 7. PalaisQuartier complex: plan view (left) and cross-section A-A (right).

Due to the large number of piles and the high pile loads a pile load test has been carried out within the “PalaisQuartier” project. Osterberg cells have been installed in two levels in order to assess the influence of pile shaft grouting measures on the limit skin friction of the pile in the Frankfurt Limestone layer (figure 8).

The test pile with a total length of 12.9 m and a diameter of 1.68 m consists of three segments and has been installed in the Frankfurt Limestone layer 31.7 m below surface.

The upper pile segment above the upper cell level and the middle pile segment between the two cell levels can be tested independently. Pile shaft grouting measures have been carried out for the middle pile segment.

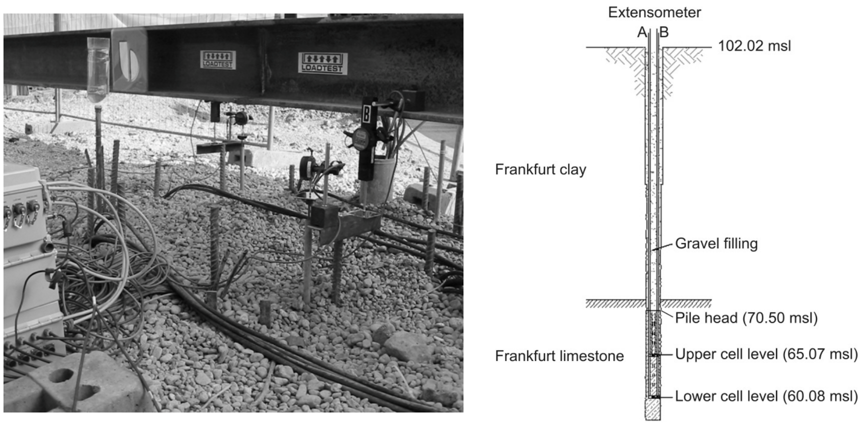

Figure 8. Pile load test setup.

In the first phase of the test the upper part was loaded by using the middle and the lower part as abutment. A limit load of 24 MN could be reached (figure 9). The upper segment was lifted 1.5 cm, the settlement of the middle and lower part was 1.0 cm. The mobilised shaft friction was about 830 kN/m^2.

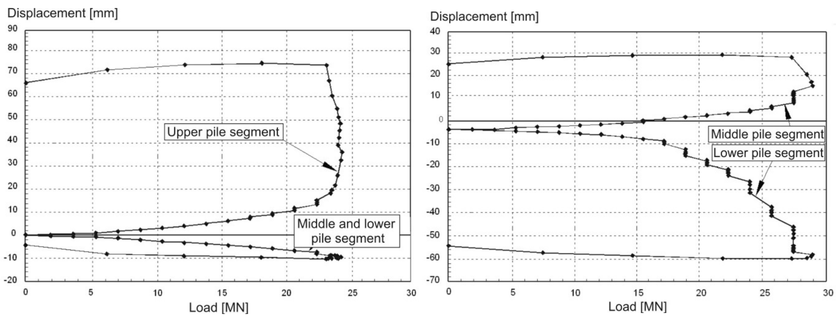

Figure 9. Load displacement curves of the test phase 1 (left) and the test phase 2 (right).

Subsequently the upper pile segment was uncoupled by discharging the upper cell level. In the second test phase the middle pile segment was loaded by using the lower segment as abutment. The limit load of the middle segment with shaft grouting was 27.5 MN (figure 9). The skin friction was 1,040 kN/m^2, this means 24 % higher than without shaft grouting.

Based on the results of the pile load tests using Osterberg cells the majority of the 290 foundation piles were made by applying shaft grouting measures. Due to the findings of the load tests the total pile length was reduced significantly.

4 GEOTHERMAL USE OF DEEP FOUNDATION ELEMENTS

4.1 Geothermics for environment-friendly cooling and heating

Beyond their function as bearing elements deep foundation elements can also be used for the environment-friendly cooling or heating of buildings. In that case the foundations are used twofold: as load carrying foundation elements and as energy absorbers as illustrated in figure 10 on the left (Katzenbach et al. 2008c).

Several different deep foundation structures may be thermally activated, e.g. precast driven piles, bored piles and barrette foundations (von der Hude et al. 2007). In figure 10 (middle and on the right) and figure 11 the application of the geothermal activated deep foundation elements and the collecting pipes are shown.

Heat exchanger tubes are fastened to the reinforcement cage usually on the inner side of the cage. Together with the reinforcement cage the heat exchanger tubes are lowered into the borehole, which afterwards is being concreted. Using precast foundation elements, this process takes place off-site in the factory. Through the tubes a heat carrying fluid circulates to transfer the energy between the ground and the building.

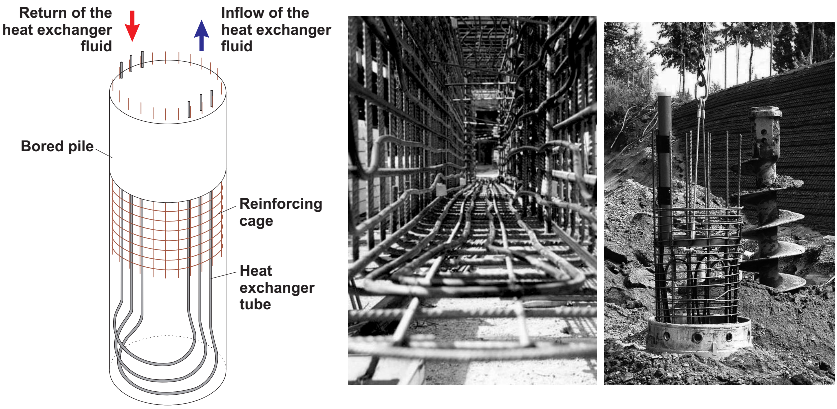

Figure 10. Left: energy pile (Brandl 2006); middle: diaphragm wall reinforcement cage equipped with heat exchanger tubes; right: installation of the reinforcement cage for a bored energy pile.

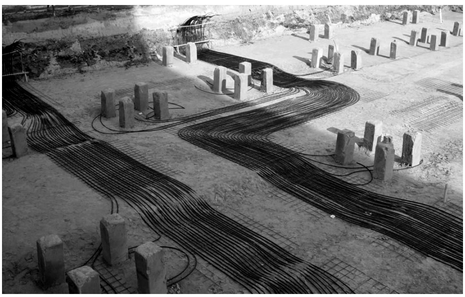

Figure 11. Field of thermally activated driven piles with collecting pipes.

The difference in temperature between the fluid and the surrounding soil causes a temperature equalisation by which the thermal energy is transferred into the soil respectively out of it. The heat transport or transfer takes place as material-bound or non-material-bound transport towards the lower temperature level. It can be described by the differential equation 5.

$$div\left(\left(\lambda+(\rho c)_f\,\delta_\lambda|v|\right)grad\,T\right)-(\rho c)_f\,div(vT)+\dot{Q}_i=\rho c\frac{\partial T}{\partial t} \tag{5}$$

In equation 5:

λ	= thermal conductivity [W/(m·K)]
$(\rho c)_f$	= volumetric heat capacity of the fluid phase [J/(m³·K)]
δ_λ	= heat dispersivity [m]
v	= fluid velocity [m/s]
T	= temperature [K]
$\dot{Q}_i$	= heat sources [W/m³]
ρc	= volumetric heat capacity of the subsoil [J/(m³·K)]

By seasonally extracting and depositing energy the subsoil can be used as a Seasonal Thermal Storage, charged respectively discharged similar to an accumulator. An optimised process consists of two different services for winter and summer. In the winter the Seasonal Thermal Storage is discharged i.e. the temperature of the surrounding subsoil is decreased and the energy detracted from the soil is used for heating the building. During the summertime the thermal storage system runs reversely that means the building is cooled and the heat affecting the building is used for recharging the thermal storage.

4.2 Geothermics in engineering practice

At the above presented project "PalaisQuartier" the possibility to use the piles that are necessary for carrying the building loads and for the retaining wall as energy piles was already discussed in the early planning stages of the project.

As a result of the comparably low additional costs for the required installation equipment and the high energy recovery potential of the energy pile system, the geothermal concept was realised in the project. For the thermal activation of the subsoil almost all foundation piles were equipped as energy piles. In the areas of the skyscraper building core, where the foundation piles are set very close together, only selected piles were equipped with heat exchanger tubes. Overall 262 of the 302 foundation piles were equipped as energy piles. From the total number of 543 retaining wall piles every second of the 289 reinforced piles, except in partial areas, were equipped as energy piles, totally 130 piles. Hence, a total of 392 foundation and retaining wall piles with a total heating and cooling power of nearly 1,000 kW will be available by the thermal usage of the subsoil.

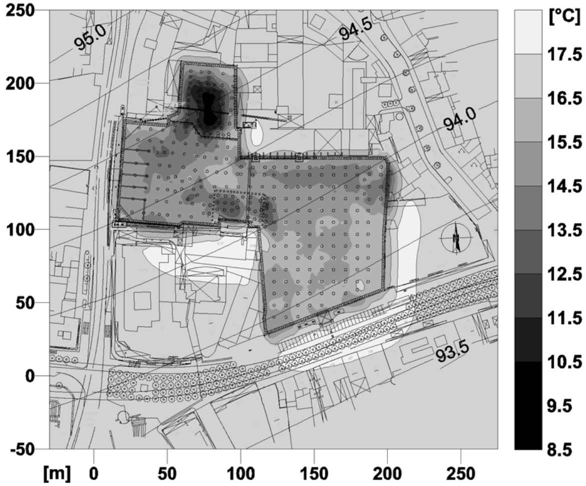

Figure 12. Calculated isotherms after winter operation with ground water level isolines (msl), horizontal section in the limestone (Katzenbach et al. 2007).

The energy concept for the building provides for a Seasonal Thermal Storage operation of the energy piles. The annually moved energy quantity of the energy pile system was estimated in the dimensioning to approximately 2,350 MWh/a for heating operation and 2,410 MWh/a for cooling operation. The Seasonal Thermal Storage operation of the system is thus nearly balanced. The operation of the geothermal storage has been simulated with three-dimensional numerical calculations with coupled groundwater flow and heat transport models based on the Finite-Element-Method (FEM) in order to analyse the thermal impact on the subsoil and the possible influence on neighbouring properties (figure 12).

5 REUSE OF PILES

5.1 Reuse of piles as enhanced Geotechnics

If existing foundation elements under new constructions are not reused they have to be avoided or removed. The avoidance of existing foundations may require additional transfer structures, for example to bridge existing pile groups and to transfer the load to areas where new piles can be installed. The repeated avoidance will become increasingly expensive as the space for new foundations is diminishing. This will require more and more larger piles and transfer structures. This procedure adds to the congestion of the ground and therefore it is not sustainable. The removal of piles will affect the surrounding subsoil and the bearing capacity of piles installed at the same location (Katzenbach et al. 2006a).

Only if position and capacity of required and existing foundation coincide a reuse of the preloaded existing foundation will be considered. Otherwise additional foundation elements have to be installed or an upgrading of existing foundations has to be taken into account. In any case, reliable information about the existing foundation has to be collected. First of all, the foundation designer needs to know the exact position and geometry of the foundation elements. The integrity and durability of the foundation components have to be assessed (Briaud et al. 2002). The external and the internal bearing capacity have to be proved (Butcher et al. 2006).

5.2 Reuse of foundation elements in engineering practice

For the Hessian parliament the old plenary building was built on an irregular grid of bored cast in place concrete piles of various diameters and lengths connected by ground beams of various profiles (Katzenbach et al. 2006b). As-built drawings of the piles have been available. Position, diameter and length as well as the maximum pile load could be found in the documents provided by the former contractor. In order to reuse the existing piles all information on these had to be evaluated as the former contractor provided information without any guarantee only (Chapman et al. 2003, Taffe et al. 2005).

Integrity testing by low-strain method was carried out (DGGT 1998, Kirsch et al. 2003). If a crack was preceived in the upper part of the pile above the ground water table, the pile was cut off and tested again (figure 13).

Figure 13 shows the results of the testing of three exemplary piles. The curve of velocity of the pile top shows one major peak coming from the hammer blow on the pile top. The expected pile length l_{exp} of pile BP 2.2 (figure 14a) was 4.30 m. At a depth of about 1.0 m a major reflection probably caused by a defect was perceived. After this first testing, this pile was cut of until this crack and tested again. The expected length of pile BP 2.5 (figure 14b) was 5.4 m. The reflection at a depth of 5.0 m could be caused by a defect or by the pile toe. Figure 14c) shows the shape of reflection of a pile with the expected pile length found by the testing. The geotechnical bearing capacity of each pile intended for reuse was calculated by taking into account the results of the testing regarding the geometry and integrity. Current pile shaft and base resistance values as well as factors of safety were applied in order to calculate the applicable load of each pile.

Figure 13. Integrity testing of existing pile.

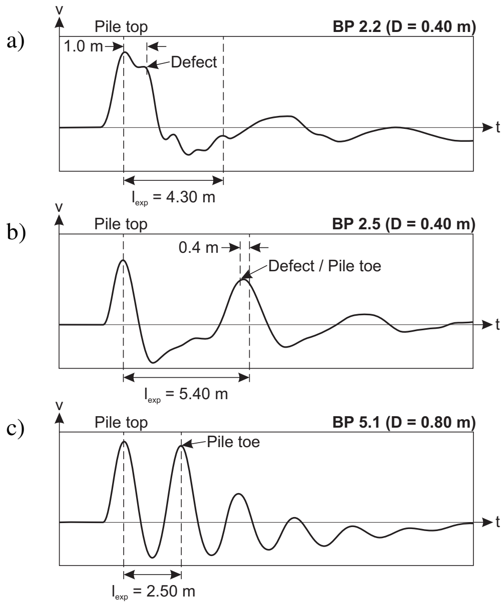

Figure 14. Measured results of piles.

6 THE TU DARMSTADT ENERGY CENTER

A reliable, economic and sustainable energy supply is the focal point of the existence and development of our society. Hence, the future development of energy systems represents one of the most important technical, social, economic and political challenges, which requires an interdisciplinary cooperation between science, industry and politics. In view of the complexity of these challenges, the TU Darmstadt Energy Center was founded at Technische Universität Darmstadt as an Academic Center.

Main focuses of the TU Darmstadt Energy Centers' researchers from 25 research groups ranging from Engineering Sciences over Natural Sciences to Humanities, Social Sciences and Economics (figure 15) are:

- Electrical energy supply and energy conversion
- Energy efficient buildings
- Power plant technology
- Renewable Energies and climate protection
- Low-temperature fuel cells
- Photovoltaics
- Geothermal energy
- Solar-thermal energy

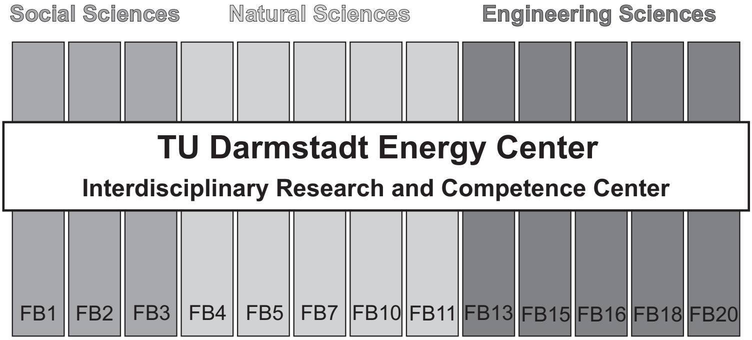

Figure 15. Participating faculties of the interdisciplinary research and competence center TU Darmstadt Energy Center: F1 – Law and Economics, F2 – Social Sciences, F3 – Humanities, F4 – Mathematics, F5 – Physics, F7 – Chemistry, F10 – Biology, F11 – Materials- and Geosciences, F13 – Civil Engineering and Geodesy, F15 – Architecture, F16 – Mechanical Engineering, F18 – Electrical Engineering, F20 – Information Technology.

The TU Darmstadt Energy Center has the task to provide the academic and organisational resources for the efficient and interdisciplinary research and development projects at Technische Universität Darmstadt in all energy related fields. The TU Darmstadt Energy Center focuses on the research and development of technologies and structures which are necessary to guarantee a reliable, economic and sustainable energy supply. Therefore, the establishment of appropriate political, legal and social basic conditions and the implementation of new technologies and structures in the market are necessary.

The establishment of a balanced energy supply from various sources, as well as the enhancement of the energy efficiency in the industrial sector, in transportation and in the building sector engineering in terms of climate protection and protection of fossil resources is intended to be realised through interdisciplinary and inter-facultative cooperation. Therefore, based on the independency and academic objectivity of the Technische Universität Darmstadt, the TU Darmstadt Energy Center develops academic expertise, gathers academic-based and neutral information for the public, consultants and decision makers in economy and politics.

Main tasks of the TU Darmstadt Energy Center are the development and the enhancement of assessment criteria, evaluation standards, test systems, integration activities and management strategies in the energy industry sector as well as the construction and the test of demonstrative projects, expert advice for administrative institutions and the integration of improved classical and newly developed energy technologies and of regenerative energies. The establishment of a sustainable energy supply has to be geared to the following leading principles:

a) The transition to a sustainable energy supply and the minimisation of energy consumption is carried out consistently on the basis of a continuing enhancement of traditional technologies. Innovative developments in the field of regenerative energies accelerate this development.
b) Future energy supply and minimisation of the energy consumption call for the integration of different technologies towards an energy mix accepted by society.

c) The development and implementation of sustainable energy technologies for an integrated energy economy is evolutionary. New structures arise for the integration of different energy technologies, which emerge as an optimal energy economy.

The TU Darmstadt Energy Center is the contribution of the Technical University Darmstadt to national and European research on energy and the climatic change.

The cooperation and integration of professionals and decision makers in politics, science, economy and administration are an essential requirement for the success of TU Darmstadt Energy Center. Therefore, the TU Darmstadt Energy Center is affiliated technically and scientifically with the non-profit association "Advisory Board of the TU Darmstadt Energy Center" with members from academia, politics, economy and administration.

The academic core of the TU Darmstadt Energy Center is the Graduate Master Degree program "Energy Science and Engineering" which is currently being established. Within this two-year program students can choose among a comprehensive variety of subject combinations: The innovative concept of this Master Degree Program includes the independent conduction of research and teaching in multidisciplinary courses and project-related teamwork. Courses in the program focus on regenerative energies, energy scenarios and the climatic change, energy technology in construction and mechanical engineering, materials-science fundamentals of regenerative energy systems, physical and chemical fundamentals of energy exchange, simulation and optimisation in energy technology, furthermore economic and social aspects of energy supply and energy consumption (figure 16).

Besides the interdisciplinary course program, early involvement of students in active research and an extensive mentoring and support concept are essentials of the education. The Master Degree program "Energy Science and Engineering" is currently being established and is intended to start in the winter semester 2011/2012.

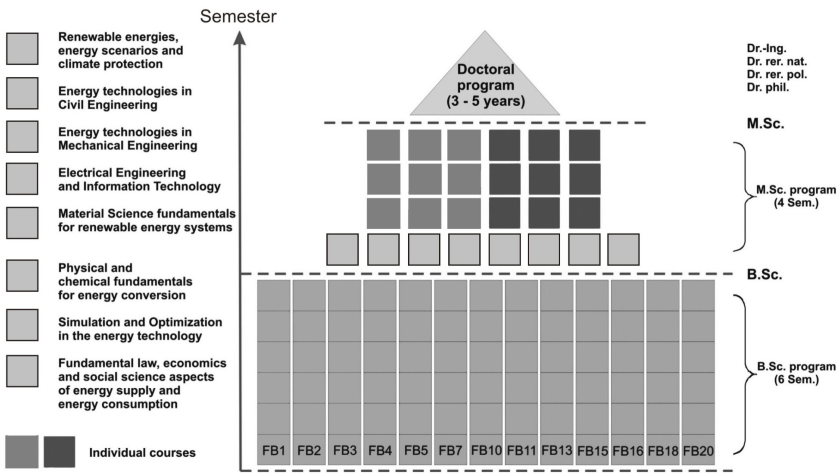

Figure 16. Structure of the Master Program "TU Darmstadt Energy Engineering".

7 CONCLUSIONS

In order to monitor behaviour of complex foundation systems like Combined Pile-Raft Foundations (CPRFs) measurement devices need to be installed as part of the observational method as well as for a better understanding of the subsoil-structure interaction with the objective to continuously minimise the required total foundation volume. As good basis for a cost optimised design of deep foundation elements, advanced load test need to be carried out. The geothermal activation of deep foundation elements for heating and cooling purposes is a reliable way of reducing the operation costs and the environmental impact of the operation of buildings. Regarding the reduction of costs and natural resources for new projects on existing foundation elements the reuse of these elements should be aimed.

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Inspection and maintenance of old bridges

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1 INTRODUCTION

In the design practice, we are used to refer to recurrence intervals of centuries. For instance, in the European countries, 200 years is the return period usually assumed for floods. But, if we consider the real life of a structure, how long do two hundred years last? In fact, two hundred years ago, the material characteristics, the building technologies and the theoretical know-how were very different from the present ones.

As regards to the materials, for instance, the industrial process to produce cast iron was invented at the end of eighteenth century (Cort and Wilkinson), while a steel with modern characteristics was patented at the middle of 1800 (Bessemer & Siemens and Martins). John Roebling began producing wire ropes in Saxonburg in 1841.

The second half of the nineteenth century saw the birth of new technologies, when the first experiments on reinforced concrete were carried out (Lambot, Hyatt, Coignet, Monier, Koenen). The formulation of the basic criteria for reinforced concrete design (the steel works in adherence with the concrete; concrete and steel form together a system homogenous on average) dates back to 1887, when the experimental studies and the remarks by Wayss and Bauschinger were published. In 1902, Mörsch published his famous book Der Eisenbetonbau (Mörsch 1902). The first experiments and applications of prestressed concrete structures were proposed by Freyssinet, who patented his "Procédé de fabrication des pieces en béton armé" in 1928 (Freyssinet 1950). In 1933-36 Abeles carried out the first experiments on partially prestressed beams and decks (Abeles 1937).

At the same time, the nineteenth century also gave us the basis of the strength of materials and of the theory of structures (Timoshenko 1953). In particular, with the growing use of steel in structures, more complete investigations of various type of truss structures became necessary and the first methods to deal with statically indeterminate structures were proposed.

The great arch and truss steel bridges like those of Gustave Eiffel (Garabit Bridge, 1880-84; Maria Pia Bridge in Porto, 1877) and of Anghel Saligny (Danube crossing in Cernavoda, 1885-1890) date back to those times. The first long span reinforced concrete bridges appeared in the first decades of the twentieth century, when Hennebique built the Ponte Risorgimento (Rome, 1911) and Freyssinet the Saint Pierre du Vauvrai Bridge (1919). A comprehensive history of that pioneer age can be found, for example, in the books of Trojanović (Trojanović 1960) and Leonhardt (Leonhardt 1982). An epic history of the greatest cable suspended bridges and of their designers was written by Henry Petrowsky (Petrowsky 1996).

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Dealing with old structures, we cannot avoid framing them into the context of their time, before assuming any sort of decision and/or to choosing any sort of intervention.

The major aspects that must be taken in considered usually regard:

- possible changes in the geomorphology of the territory where the bridge is located. Topographic surveys can detect if any settlements have occurred both at a local and at a global scale, due for instance to gas extraction from the subsoil. Another issue is represented by the riverbed geometry, both in plan and in the shape of bathymetric conformation;
- possible changes in the attitude of the bridge, made evident by vertical irregularities of the road level, by rotations of the piers, by excessive vertical displacements of the deck or by abnormal horizontal displacements of the bearing supports;
- conservation or damaging states of the structural elements (foundations, piers, deck) and of the joints, of the bearing supports and of the devices intended to drain the water from the deck.

All these issues concern environmental influences on the bridge service life. The loads consist of self weight, of the stream flow, of the debris loading and of the wind. The distortions may be caused by settlements of the foundations of the piers and of the abutments.

But a bridge is primarily a transportation link. Hence, many bridges modifications are caused by new traffic needs. Again, we remain struck by the strong differences among the traffic loads given by present codes and those assumed at the time of construction: for instance, one hundred years ago, the load train for road bridges was made of a row of 16 metric ton carts, 6m long, pulled by a team of four couples of horses, 10 m long and (4 × 1,4) t heavy (13.5 kN/m). The maximum rail bridge loads were 30 – 60 kN/m.

It must be remembered that, in those times, the speed was also lower and that usually two lanes only were sufficient. Hence, when possible, an actual rehabilitation of an old bridge involves a widening of the road platform and an intervention on those structural elements which need to be strengthened in order to carry the new loads.

This paper gives an account of studies and rehabilitation works carried out on a group of bridges located in the North of Italy and belonging to the main typologies used in the years between 1850 and 1970. Part of these bridges lie on the reach of the Po river which delimits the southern border of Lombardia. The other bridges cross minor rivers.

Recalls will be made on the surveys and monitoring activities and on the problems addressed during the rehabilitation works.

Synthetic descriptions of the main interventions on the foundations, on the body of the main structure and on the special devices will be given.

2 BRIDGES AND ENVIRONMENT. SURVEY OF A GROUP OF BRIDGES ALONG THE PO RIVER.

2.1 *The Po Basin.*

The Po is the main Italian river. It rises in the western Alps and flows to the Adriatic sea, 652 km away. Its hydrographic basin is 74,970 km^2 wide and receives 43 tributary rivers. The total length of the embankments is 3564 km.

With the exception of the upper reach, until the end of nineteenth century the crossing of the Po was carried out through river ferries and floating bridges.

Due to the wide span of its main branch, traditional masonry and stone arch bridges involved limited spans resting on a high number of piers, having basements in an insidious and wandering riverbed.

The first long span bridges appeared with the diffusion of the steel truss girders having an isostatic Gerber scheme. Many of these road and rail bridges, although after some reconstruction work, are still operating.

After WWII, thanks to new materials and new technologies, regarding both foundation works and piers and decks, many new bridges were built, with a wide use of prestressed reinforced concrete. The main challenge during the design and erection phases was not represented by the spans (usually 50 – 70 m on average), but by the interaction with severe fluvial hydraulics, characterized by cyclic floods, which often overtopped the embankments, invaded the floodplains and sometimes upset the countryside and villages at the two sides of the river.

We have a fairly complete knowledge of the historical floods of the Po river since a remote age. The main floods of the last hundred years occurred in 1926, 1951, 1994 and 2000.

2.2 *A wide surveying campaign.*

After the 2000 flood, the Compartment for the Lombardia region of the ANAS (Italian Agency for Roads) promoted a campaign aimed to survey the state of the piers, of the basements and of the foundations of the main bridges crossing the Po and serving roads of national interest in the Lombardia region.

Such a campaign was meant to provide a first evaluation of the bridges state and to detect possible critical conditions of the piers and foundations, paying particular attention to hydraulics causes of instability, like erosion and scour.

The bridge main characteristics are listed in Table 1 and their locations are shown in Figure 1a.

2.3 *Surveying and Monitoring.*

Surveying and monitoring consisted in the following activities:

- preliminary exam of each bridge on the basis of the documents (original drawings and reports) available in the archives;
- general visual inspection;
- geometrical survey, with dimensional cross-checks with the original drawings; detailed description of local damage states;
- survey of the overall attitude of the bridge, with respect to horizontal and vertical references; verticality checks of the piers; levelling of the roadway;
- bathymetric survey, in order to draw the geometry of the riverbed, to detect possible scouring signals near the piers;
- underwater surveys, aimed to detect cracks or clefts in the submerged parts of the piers, as well as traces of erosions or scour holes at the piers basis;
- vertical boreholes in the piers aimed to measure their buried depth; echo-soundings, used to check the actual depth of the piers above the piles;
- geognostic boreholes, with the performance of SPT and CPT tests and with collection of disturbed and undisturbed soil samples.

The mean cost of the surveys versus the overall length of the bridges is shown in Figure 1d.

Table 1. Characteristics of the main bridges examined (see Figure 1.a)

N.	River	Place and year of construction	Total length [m]	Length over riverbed [m]	Piers in flood-plains	Piers in riverbed
1	Po	Casalmaggiore, 1958	1205	580	3 + 25	6
2	Po	Viadana, 1967	1670	734	36 + 6	5
3	Po	Borgoforte, 1961	1137	472	9 + 3 + 0	4
4	Po	San Benedetto Po, 1964-66	613	613	5	4
5	Po	Ostiglia, 1929/1947	511	511	1	5
6	Po	Piacenza, 1908/1947	1096	607	12 + 5 + 3	2
7	Serio	Montodine, ~ 1970	64	64	0	1
8	Oglio	Pontevico, ~ 1970	90	90	0	2
9	Oglio	Sarnico, ~ 1970	87	87	0	5
10	Oglio	Montecchio 1, ~ 1970	270	270	9	2
11	Oglio	Montecchio 2, ~ 1970	90	90	1	2
12	Oglio	Breno, ~ 1970	403	403	15	2
13	Po	Pieve Porto Morone, 1961	1250	1250	10	5
14	Po	Becca, 1912	1040	1040	3	9

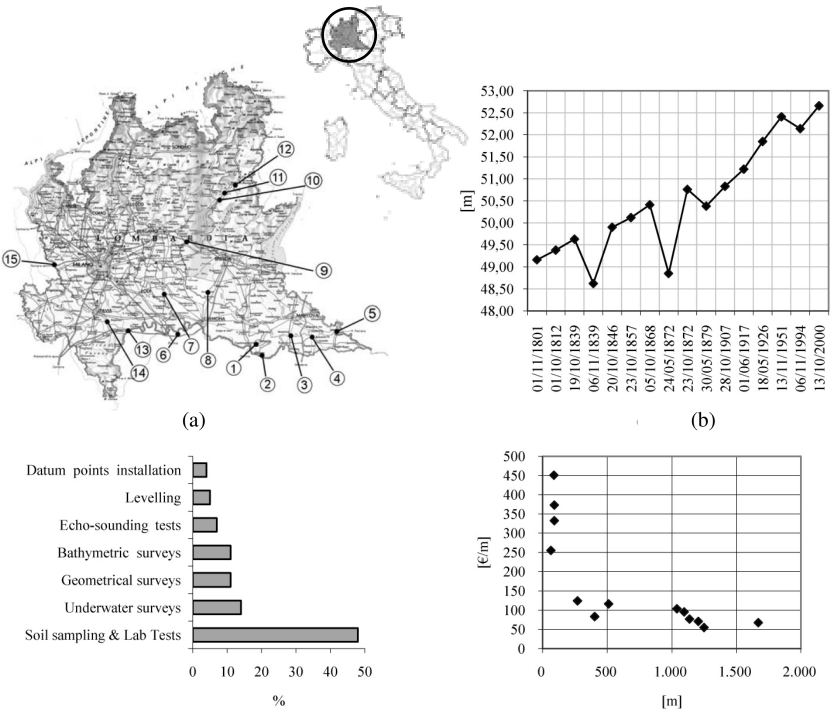

Figure 1. (a) Position of the main bridges listed in Table 1; (b) maximum hydrometric at the Piacenza gauging station in the last two centuries; (c) cost distribution for different types of test; (d) mean cost of the surveys per meter vs overall length of the bridges.

2.4 *Laboratory and Office Activities.*

The results of the laboratory tests carried out on the soil samples were used to define the load carrying capacity of the original foundation systems, as well as to design the strengthening works on the insufficient ones.

The office activities consisted in hydraulic engineering and structural assessments. For each bridge a comprehensive report was compiled. These reports gave a final assessment of the actual state of each bridge and highlighted its possible critical faults.

Each bridge was classified and given a priority level which implied recommendation for ordinary or extraordinary maintenance activities, or, in case the safety of the structure was found inadequate, for radical strengthening works.

2.5 *Main results drawn from the bridge inspection.*

Floods are a common experience for people who live at the Po riversides. Now, comparing the recent surveys with the historical data, it is possible to observe a rising trend of the maximum flood levels and, in recent years, a higher frequency of the flood events.

According to the experts of environmental hydraulics, such a phenomenon is mainly due to anthropic factors, like a progressive waterproofing of the basins, due to urban and infrastructural growing, the removal of expansion zones and the increase of river reaches confined by embankments. Climate changes may also have contributed to these effects.

Figure 1b shows the maximum hydrometric levels recorded by the Piacenza measuring station during last two centuries and confirm these remarks.

Another element which was confirmed is the depth of the scour in the rapid transient phase as determined according to the recent Po Basin Authority specifications, which agrees with the most widely recognized formulations (Hamill 1999). These values of scour depth appeared quite higher than those assumed in the past (Figs 2a, b) and strongly condition the load carrying capacity computation of the foundations and of the piles.

As regards to the body of the piers, it was not found in a bad situation. Some masonry piers presented losses of mortar among the masonry courses. Both masonry and reinforced piles presented traces of collision with the small boats and ships which sail the middle and final reaches of the river.

For the main bridges, the position and the orientation of the piers with respect to the main flow was judged correct. In some minor bridge, spanning over tributary rivers, some cases of wrong foundation basement were found (Figs 2c, d). An insufficient deepening of the basement and an orientation causing the maximum interference obviously increase the erosion and the local scour effects.

Another general consideration regards the soundness of our probabilistic design procedures, tuned to values of return periods (100, 200 years). The surveys of the most recent bridges, for which it was possible to compare the present riverbed profile with that of thirty/forty years ago, showed cases of strong riverbed changes, with the movement of the main current from one alignment to another and also with the growth of temporary islands downward the old main current.

The underwater surveys reported that, even after a long time from the end of the flood event, a systematic encumbrance of debris remained at the basis and along the body of the piers. This is a problem of ordinary maintenance. But, who is in charge of the debris removal? Is it the river Authority or the bridge Authority? More simply: who has to pay?

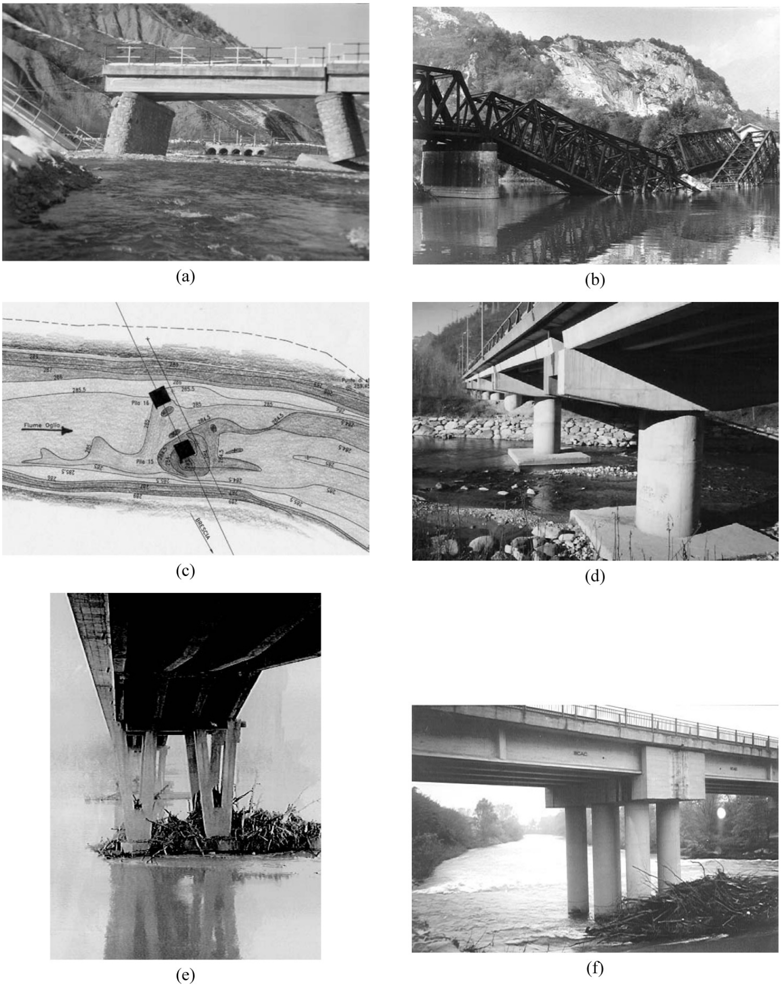

Figure 2. Scour effects and debris action on piers in the riverbed: (a),(b) collapses caused by the scouring action in bridges crossing river Po’s tributaries; (c),(d) effects of the position, of the orientation with respect to the water flow, and of the depth of the foundations in a small river; (e), (f) multi-columns piers acting as grids in the formation of debris rafts.

3 THE NEEDED REPAIR INTERVENTION

Once the data acquired during the inspections and surveys had been analyzed, different repair intervention were set up. These interventions were carried out on:
- the foundation systems (piers, basements and piles);
- the main structures of the bridges;
- their complementary or special devices.

4 INTERVENTIONS ON FOUNDATIONS

Nowadays, the need for an intervention on the foundations arises mainly after their stability has been checked according to new codes and regulations, which lead to higher depths of the estimated scour holes and higher values of the acting forces. This brings to refurbish and strengthen the original foundation systems in order to obtain a suitable safety level.

The strengthening interventions are usually based on two contributions. The first one consists in protecting the area surrounding the piers by means of big bags containing massive stones. Such a work stabilizes the riverbed and leads to less severe expected scour depths. The second intervention consists in strengthening the pier basement.

Usually the strengthening is carried out in one of these two ways:
- when the body of the pier is sufficiently compact and massive, like in the case of masonry piers, new piles are driven across the body itself;
- when this is not possible or when previous repairing interventions occurred in the volume of the pier, new piles are driven around the perimeter.

A common problem of both these types of intervention is the accomplishment of a robust connection between new and old structures.

Examples of solutions for different foundations problems are presented in the following.

4.1 *Strengthening of the foundations of a bridge of the nineteenth century.*

One of the two bridges over the river Adda in the town of Lodi is the masonry bridge built in the years 1863 – 64 by the Milanese Architect Gualini. It is made of nine shallow arches spanning 18.90 m each, for a total length of 175 m (Fig. 3a).

In 1970 – 71, the deck of the Lodi Bridge was refurbished in order to comply with the new traffic loads (Fig. 3b), and a weir was built 200 m downstream in order to protect the basement of the bridge. In the following years, the weir caused some floods which affected the town riverside. This brought, after new hydraulic assessments carried out in 2006, to the decision of lowering the weir, which, in turn, would imply an increase in the flow speed, thus exposing the foundations to more severe service conditions. Soil samplings and laboratory tests, and subsequent geotechnical and structural assessment were performed to ascertain whether the foundations were able to cope with the worsened conditions: the outcome was that the foundation system was not safe even in the current state. It was therefore decided to carry out significant strengthening works.

Some remedial works had already been carried out in the past, after some foundation settlements had been observed. In fact, in 1947, each foundation had already been strengthened and their basement protected against corrosion and scour.

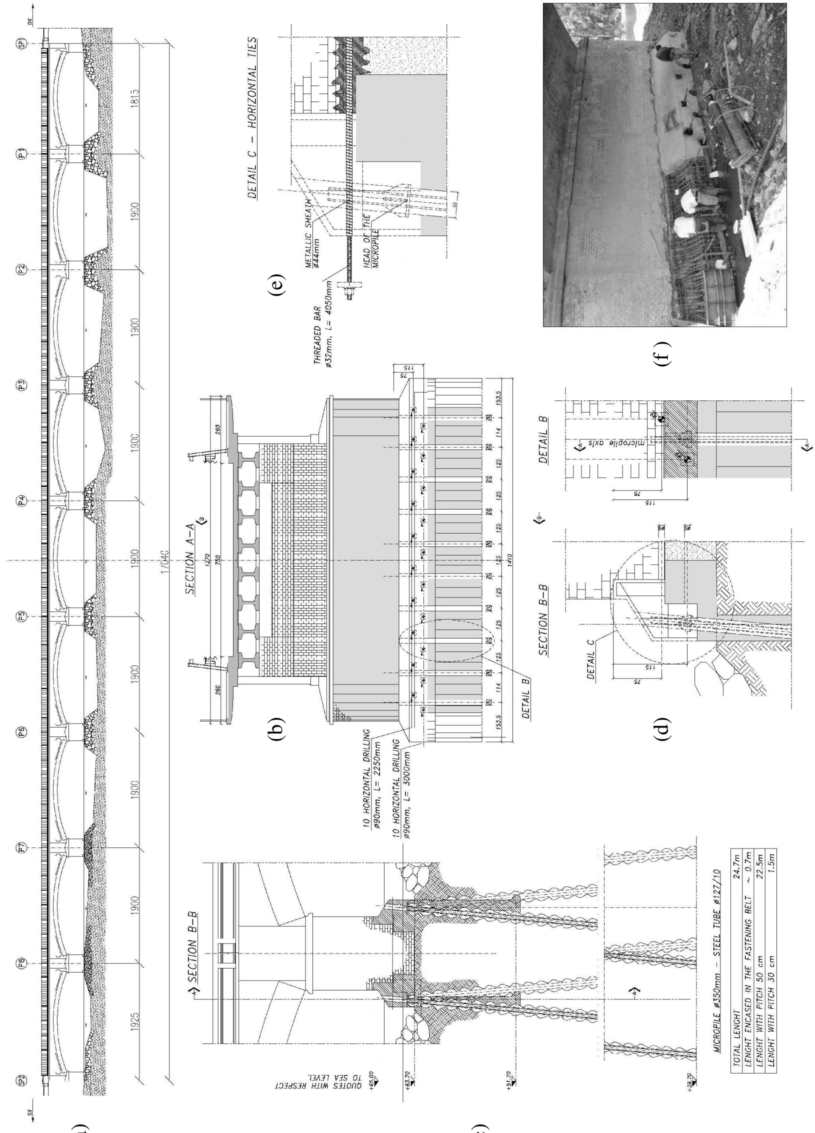

Figure 3. Lodi Bridge (1863-64). (a) front view of the bridge; (b) transversal section showing the new deck, made of precast prestressed beams, the position of the new piles and that of the threaded connecting bars; (c) arrangement of the micropiles at the two sides of a pier; (d), (e) details of the R.C. hooping crown; (f) photograph of an intermediate phase of the works.

The new intervention (which is currently ongoing) substantially recalls the old one. Twenty new micropiles, having a diameter of 0.20 m and 24.70 m long, were drilled alternatively at a ±5° angle along the sides of the basement (Figs 3b, c). The micropiles were reinforced by valved steel tubes having a diameter of 127 mm and a thickness of 10 mm (Fig. 3c). Their position was defined so as not to interfere with the old piles. The old concrete crown was demolished step by step, paying attention not to cut the reinforcing bars. The demolition was accompanied by the contemporary reconstruction of reaches of the new, wider crown. Twenty horizontal threaded bars, having a diameter of 32 mm, passing across the pile body and placed at two different levels (Figs 3b, d, e), strongly connect the two opposite sides of the crown. Figure 3f shows an intermediate phase of the works.

Before and during the works, the attitude of the bridge was topographically surveyed.

5 MAIN STRUCTURES OF THE BRIDGES

The interventions needed on the main structures of a bridge may be summarized as follows:

- strengthening of the carrying structure due to deficiencies in their load bearing capacity, caused, for instance, by settlement effects, or by corrosion of the reinforcing bars or of the prestressing steel in critical sections;
- refurbishment and adjustment of the structure to new codes prescriptions, involving, for instance, heavier load conditions;
- changes in geometry, due to the need of widening the road platform.

In the following, the refurbishment of an old arch bridge is examined.

5.1 *The Railway Bridge across the Gaggione River.*

5.1.1 *The structure.*

The bridge across the Gaggione River was built in 1885 along the railway which connects the city of Milan to Varese, 60 km away.

The bridge, shown in Figure 4a, has a total length of 130 m and is made of a sequence of seven stone barrel arches, which rest on six stone piers. The barrel arches have internal radius of 5.82 m and their centers are 14.00 m apart. The piers are slightly tapered: the longest one, 32.60 m high, has a section which varies from 10.00 m (width) by 5.50 m (front) at the bottom, to 4.50 m by 2.50 m at the top. The free height of the piers is interrupted by an intermediate service deck made of five shallow arches.

In 1985 – 86, the bridge was strengthened in order to carry new, heavier train loads. The main interventions regarded the basements of the central piers, the node at the intersection between the piers and the intermediate deck, and the strengthening of the intrados and spandrels of the arches.

The intrados and spandrels were enveloped in a layer of shot concrete, 180 mm thick, and reinforced with 14 mm bars arranged so as to form a mesh with a pitch of 200 mm both ways. After a strong hydrosand blasting in order to improve the chemical-mechanical adherence, the added layers were linked to the stone surfaces through a uniform curtain of pins and confined against the original walls by means of 22 mm threaded bars, piercing the body of the arches.

Other works regarded the river bed stabilization, obtained with the introduction of embankments and weirs.

5.1.2 *The problem.*

It is quite obvious that, considering this type of massive bridges, any intervention which confines tightly the masonry, and, at the same time, does not add excessive loads to the original structure, leads to an increase in the safety level. It is less immediate to define the actual static scheme and how old and new structures contribute to the overall bridge robustness.

Usually the arch is considered the main bearing structure, while the superstructures (the walls and the filling up, made of light non cohesive material), are considered as dead loads. Then, why it is so common to see clefts around the arches keystones and even, in some cases, the loss of central bricks?

5.1.3 *The bridge behavior.*

In December 1986, at the end of the strengthening works, severe loads test were carried out.

Several loading configurations were examined. The vertical displacements were measured through a set of mechanical displacement transducers (six upstream and ten downstream), having a sensibility of 1/100 mm. These gauges measured the relative displacements between the bridge extrados and a rigid, simply supported, reference beam. The reference beam supports were placed in correspondence of the vertical axis of the piers (local reference system). An electro-mechanical displacement transducer measured the vertical displacements at the crown with respect to the ground (absolute reference system). At the intrados and at the lateral walls of the central section, eight electromechanical strain gauges (relative displacement transducers) were placed. Their sensitivity was 1 $\mu\varepsilon$ over a basis of 300 mm = 3.3$\mu\varepsilon$. These gauges were placed as shown in Figure 4b. Figure 4c shows the displacements obtained with the train in the central position.

The maximum vertical displacement given by the transducer with respect to the absolute reference system was v_{abs} = 0.560 mm. The corresponding displacement with respect to the local reference system was v_{loc} = 0.405 mm. The difference Δv = 0.155 mm is mainly due to the piers deformation. A FEA with membrane elements gave at the top of the piers v_{FEA} = 0.220 mm. The results shown in Figure 4c are rectified with reference to the straight line which connects the top of the piers, as computed from FEA analysis.

Figure 4b shows the vertical distribution of the horizontal strains compared to the stratigraphy of the section: the added reinforcement layer and the arch rib are in tension; the spandrels above the arch top and the infill material are compressed. A fairly good matching between numerical and experimental data was reached. A consequent comparison in terms of stresses gave, at the top (transducer No. 5) $\Delta\sigma = -0.03 \div -0.04$ N/mm^2 (FEA $\Delta\sigma = -0{,}09$ N/mm^2); at the bottom (transducers No. 1, 6, 7) $\Delta\sigma = +7.1 \div +13.0$ N/mm^2 (FEA $\Delta\sigma = 5.46$ N/mm^2). Hence, during the service life and for the applied loads, the crown of the bearing arch works in tension and the superstructure in compression.

Analogous behavior was found through a FEA for the effects of self weight. The theoretical final results of the analysis (self weight plus the weight of a E626 type locomotive) gave, for the most compressed fiber, $\sigma = -0.28$ N/mm^2, a relatively small value which can be sustained also by a moderately compacted soil. These assessments, which trust to the cooperation with materials that cannot be defined as structural in the strict sense of the word (i.e. the filling of the spandrels), cannot be used for safety evaluations.

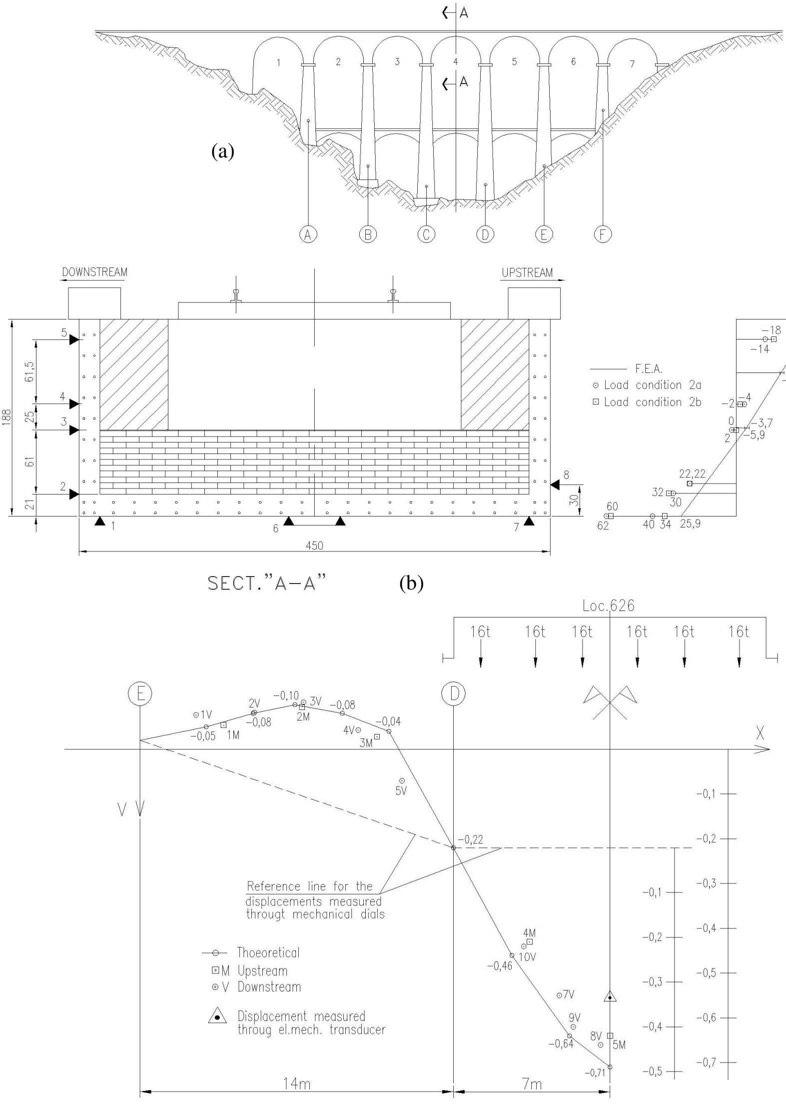

Figure 4. Gaggione Bridge (1885): (a) front view of the bridge; (b) transversal section after strengthening, layout of the relative displacement transducers and distribution of the strains in the depth of section during the loading tests; (c) comparison between theoretical and experimental vertical displacements.

Safety derives from the certainty that the evolution from the service to the ultimate state would involve the crushing of the filling material, while the line of the thrust lowers until it reaches the extrados of the bearing arch, which finally works according to the usual interpretation of its behavior. For the sake of history, this latter situation was checked also through the Méry method. However, this experience provided many suggestions for similar interventions.

6 AUXILIARY AND SPECIAL DEVICES

The service life of a bridge is strongly influenced by the regular functioning of all its different components, each one intended to carry out a specific function.

A special mention must be made to the water drainage system. It has a relatively modest cost if compared to other parts of the bridge, but it may cause severe damages. Leakages through any points of weakness in the waterproofing system or in the expansion joints may lead to significant reductions of the structural safety.

Other vulnerable systems are the expansion joints, which may show worn rubber covering, torn up bolts and permanent deformations. A cause of these drawbacks can be found in the dynamic effects induced by platform discontinuities in correspondence of the joints and to poor attention paid to the details during the construction works.

The bearing supports can also be considered as critical parts in a bridge: their substitution in old bridges is frequently not an easy task.

Finally, according to the current concepts of maintenance, the stays are as well considered as special devices that can be substituted when necessary.

6.1 *The strengthening of the ties of one of the first tied bridges. The case of the Polcevera Bridge.*

6.1.1 *The structure.*

The Polcevera Bridge was designed by Riccardo Morandi, built in the years 1960 – 1964 and put in service in September 1967.

It flies over a large railway parking lot and connects the A7 Genoa-Serravalle highway to the A10 Genoa-Ventimiglia highway, which reaches the French border. A general layout of the bridge is shown in Figure 5. The bridge is 1121.4 m long and 18.00 m wide. Its main part is made up three A-shaped frames, 90.2 m high, supporting three decks, 171.9, 171.9 m and 145.7 m long, connected to each other by means of 36.0 m long suspended girders. At a distance of ten meters from their ends, the long decks are suspended to a couple of ties, made of prestressed concrete.

This scheme repeats concepts already adopted by Morandi for the Maracaibo Lagoon Bridge (Venezuela, 1957 – 1962), the Rio Magdalena Bridge (Barraquilla, Columbia, 1969 – 1972) and the Wadi Kuff Bridge (Beida, Libia, 1965– 1971) (Morandi 1969).
This type of ties is probably the most characteristic element of the Morandi system.

The construction sequence was undoubtedly complicated, but had a clear aim: to create ties that behave as an homogenous system made of tendons working in tension and of a prestressed concrete case, working in decompression, but not in tension, under the added loads (suspended girders, finishing works, traffic, wind and temperature loads). In this way, the fatigue effects in the strands were limited thanks to the reduction of stress variations due to variable loads and, at the same, the strands were protected against corrosion.

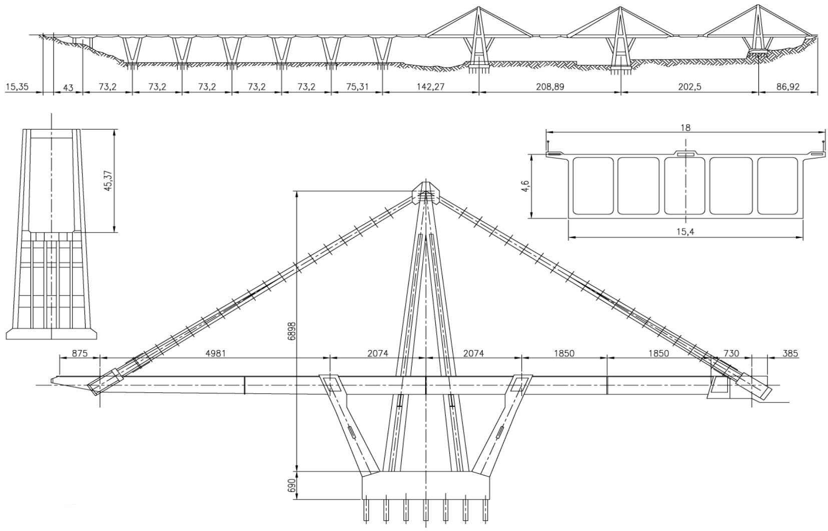

Figure 5. Polcevera Bridge (1960 - 64): view of the bridge, of an A shape frame, of the antenna and of the typical section of the deck.

6.1.2 *Needed repair interventions*

After about 25 years of service, many parts of the bridge presented severe damage states.

On the ties of frame No. 11, at the Genoa side, clear corrosion traces in the strands of the tendons appeared. Minor damages were detected on the tendons at the top of the antenna of the nearby frame (No. 10) and in other parts of the bridge.

In 1992-94, a recovery program was carried out under the guide of Francesco Pisani, who was one of Prof. Morandi’s aides at the time of the bridge design and planned the repairing intervention phases (Martinez y Cabrera 1994).

The main intervention concerned the four ties of frame No. 11. The basic concept of the intervention was to flank each original tie with a set of 12 additional modern cables, in order to transfer the suspension action from the ties to the stays.

Through specifically designed devices (collars and new anchorage systems) and following the recovery sequence (progressive tensioning phases) shown in Figure 6c, the new “composed” stay system, resulting from the coupling of the old ties to the new cables, maintains its original shape, while the stiffness characteristics remain very close to the original ones. This is important in order to maintain the original design behavior of the bridge and to avoid any change in the deflection and flexural behavior of the deck, with consequences also on the elements of the main frame.

Another aim of the progressive tension transfer from the old ties to the new composed stays, was to reduce the structural risk of excessive compression stresses in the concrete ties, avoiding potential bursting effects when the old cables were being cut.

At the end of this process, the compressive stress in the concrete ties was about $10 N/mm^2$, i.e. the same value assumed in the original design calculations.

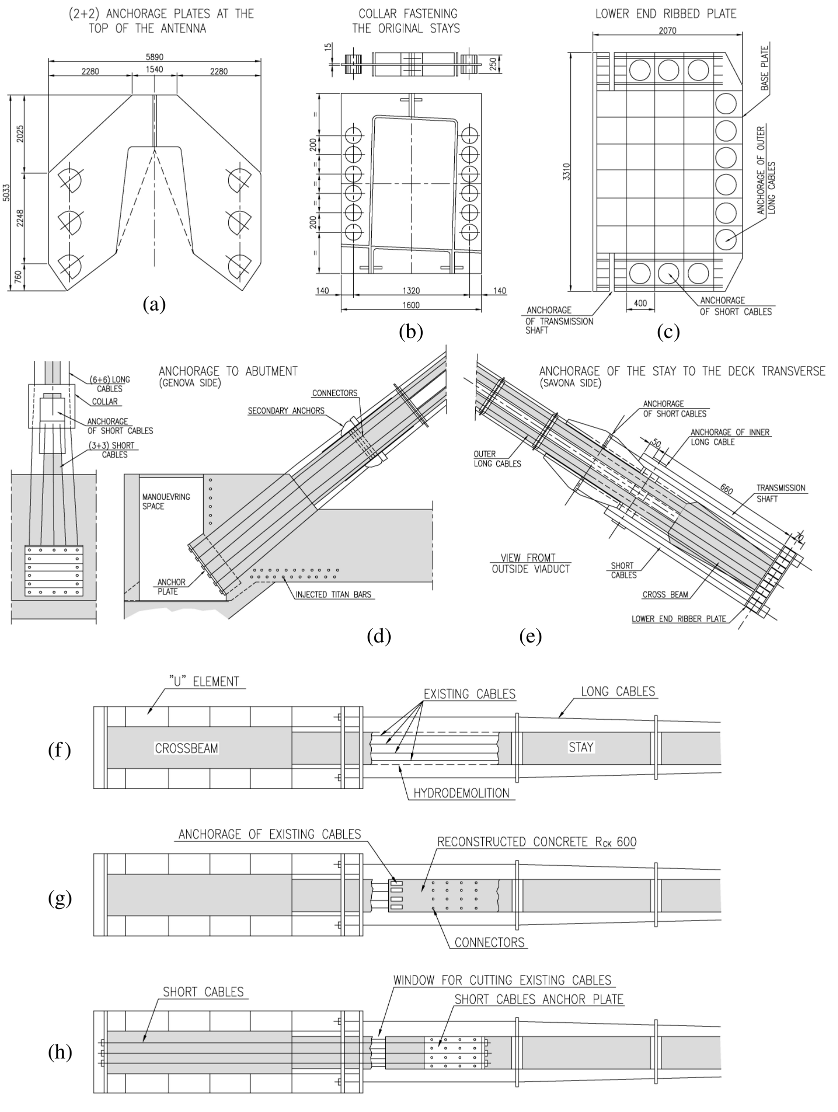

Figure 6. Polcevera Bridge (1960-64). (a) anchorage plates at the top of the antenna; (b) collar fastening the original stays; (c) lower end ribbed plate; (d) anchorage of the tie to the abutment; (e) anchorage of the stay to deck transverse; (f), g), (h) phases of demolition and of reconstruction of the end zones of the ties.

The repair works concerned also the other two frames. On frame No. 10 a local repair, aimed to strengthen the upper end of the ties was carried out. On frame No. 9, whose cables appeared less damaged with respect to the previous ones, no particular interventions were adopted. Surface protection interventions were carried out on all three frames.

It must be pointed out that the interventions were carried out without traffic interruptions. Only some traffic limitations were needed during the demolition and tensioning phases.

6.1.3 *Some final considerations on the Polcevera Bridge*

The Polcevera Bridge and other Morandi tied bridges represent an exceptional reference from the conceptual, aesthetic and technical point of view, which is even more relevant if related to the times in which these structures were built. Nowadays, however, similar static schemes, though brilliant, cannot be proposed.

According to the modern criteria of durability, the “prestressed concrete tie” does not appear as a safe solution for elements in tension. Moreover, the suspension action entrusted to a limited number of elements, makes the whole structure not very robust and the maintenance actions quite difficult.

Modern bridge configurations, characterized by a relative great number of stays (a “curtain of stays”), are designed so that, should the failure of one of more stays occur, the subsequent loss of suspension action would be made up for by other suspension elements, making the cables maintenance and/or substitution easier.

7 FINAL CONCLUSIONS

At the end of this presentation, the following conclusions can be drawn.

As regards to the relationship between the bridges and the environment, on the basis of what it was observed, the actual trend to avoid or to limit the number of piers in riverbed, and to prefer an increase in the span of the deck, is confirmed and recommended. Possible piers in the riverbed must have strong foundations, surrounded by suitable riverbed stabilization devices. The piers must be correctly placed with respect to the flow.

As far as existing bridges are concerned, it seems that the old massive and well shaped piers behave better than some types of piers built in 1960s and 1970s, which tend to rake solid debris and are more vulnerable. Moreover, a massive pier makes it easier to carry out integrative works aimed to helping the original foundations.

Speaking about the main structures, the usual remarks on the durability of reinforced and prestressed concrete structures can be recalled. A proper choice of the type of concrete, a correct curing process, adequate cover and detailing of the reinforcing bars may considerably lengthen the service life and reduce maintenance costs.

Particular attention must be paid to the drainage system. The lack of efficiency of the drainage system is one the main causes of damages and corrosion both in steel and concrete structures.

Any effort to eliminate joints or, at least, to reduce their dynamic effects, must be done.

8 ACKNOWLEDGEMENTS

My first acknowledgments are for the members of my design team: Emanuele Barbera, Paolo Galli, Chiara Malerba, Marco di Domizio, Giacomo Comaita and Giancarlo Mineo.

Many of the works presented were carried out by the Author in cooperation with the late Prof. Francesco Martinez y Cabrera, who held the chair of Bridge Theory at the Politecnico di Milano, to whom my memory and my gratitude go.

The hydraulic studies were carried by the ETATEC Company. Supervisor: Prof. Alessandro Paoletti (Politecnico di Milano).

The Polcevera intervention was conceived by Francesco Pisani. Supervisor: F. Martinez y Cabrera.

All Italian Authorities who promoted special investigations and demanding repairing works are gratefully acknowledged. Among these: the ANAS (Italian Agency for Roads) Compartment for the Lombardia region, Milan; the Lodi Municipality, Lodi; the Technical Office of the Lecco Province, Lecco; FNM SpA (North Milan Railways), Milan; SSIF Spa (Swiss-Italian Railway Company), Domodossola.

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Sustainable land use management

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1 INTRODUCTION

This paper was initially conceived in Czech, with an aim to introduce sustainable land use management concepts and its tools in an advocacy manner, suitable for Czech non specialist audiences. In this paper basic explanations are given, why sustainable land use management approaches are necessary and some of the unsustainable land use drivers are outlined. Also examined is the degree to which these drivers are being addressed in the Czech Republic. Possibilities, how to improve local sustainable land use decisions are suggested and the circular land use management approach of the project CircUse is introduced. A sister paper in Czech is also available, taking the matter of sustainable land use management further and an English version of this second paper also exists (see the section references). All these papers, presentations and also a round table of key stakeholders realized under the patronage of the Czech ministry of Environment, were designed to a) raise awareness of the land use sustainability issue amides public, and b) explain and advocate the need for integrated and coordinated approaches to the circular land management among institutional stakeholders at the national and regional level.

2 LAND USE SUSTAINABILITY

Land conversions for urbanisation are often carried out in an unsustainable way. They cause losses of arable land, reduce biodiversity and may raise concerns about food security. Increasing costs of infrastructure due to urban can sprawl weaken competitiveness of local communities and many expansions of urbanised land are not always based on rising population. These are just some of the considerations that sustainable land use management ought to include. For a number of years spatial planning was considered to be the main land use management tool for local and regional authorities. Then other factors, such as market influence, personal preferences, demographic changes, and new investment formats demonstrated that planning alone is not enough to deliver sustainable land use. It is becoming obvious, that additional sustainable land use management techniques need to be deployed. For various reasons, land use sustainability principles have been missing for a long time from most national and EU policies and only recently there are drivers (the EEA –European Environmental Agency, http://www.eea.europa.eu/ seal-

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ing reporting for example), which make their way into national legal frameworks and policies and most importantly into a wider practice.

Over the last 30 years, aspects of resources sustainability were introduced into our lives (such as energy saving, biodiversity, and material recycling). Similar approaches also need to be introduced in respect of the land use and its management. Because the land recycling processes have tangible societal and environmental benefits, measures and models need to be set up, which would turn the urbanised land reuse into a common and accepted activity, as is the recycling of drink bottles and cans.

2.1 *Loss of natural land and wasteful attitude towards a finite resource*

Natural land is a finite resource, whose benefits to our society are seldomly fully realised. The ”services” that natural land offers to our lives are mostly perceived as for ”free”. Such services however represent a very substantial value, which no urban development is usually replacing. But modern societies are ever increasing their spatial demands and therefore urbanisation and urbanised land volumes are rapidly growing. This is why sustainable land use is quickly becoming a wider than a local or a national issue, mainly because the unsustainable land uses practises have global effects on our climate. For example, urban temperatures are much higher in the urbanised areas (see figure 2). Rise in urban temperatures has several causes, for example: a) the intensive energy use causing heat gains from various human activities, b) the loss of cooling absorption capacity of natural vegetation, and c) the thermal capacities of man-made urbanised structures. Also, most urbanised activities have higher energy consumption; therefore they are much higher air polluters and have higher raw material demands. See figure 1 for the demand on natural and farm land take in the EU 25 during 1990-2000.

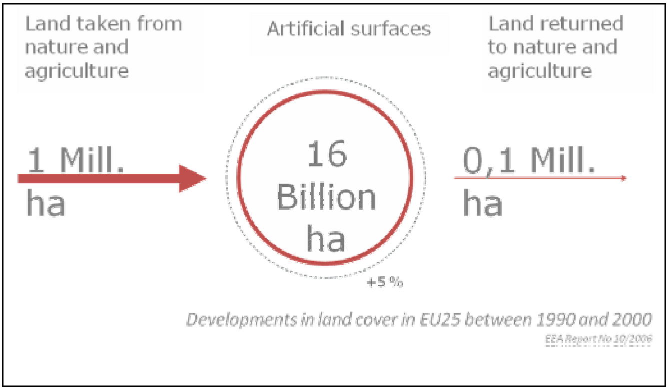

Figure 1: Natural land take 1990-2000 in EU 25 countries

2.2 *Sizing the land use issue*

Data available in the Czech Republic shows that around 15ha of land per day is becoming urbanised. When compared (respecting the size of the country) with neighbouring Germany or Austria, (which have an alarming rate 130ha/day and 35ha/day respectively), Czech land conversion figures may not look so bad, at approximately 55% of

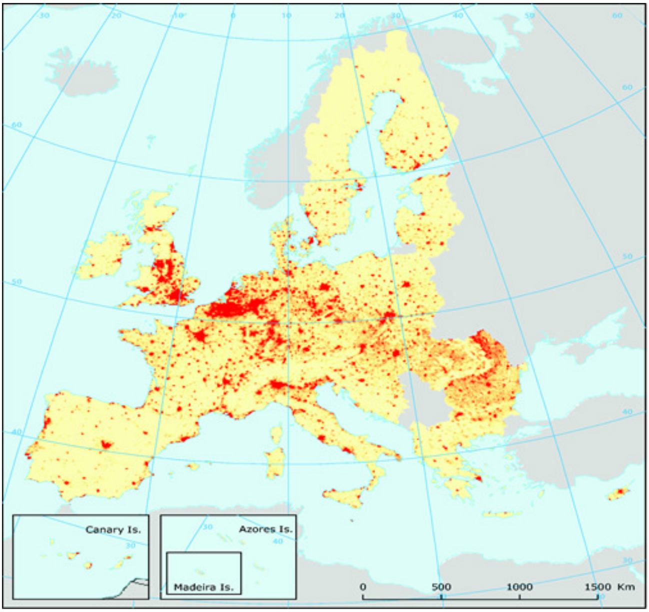

Figure 2: Urban "temperatures" in EU, source EEA

Germany´s and 45 % of Austria´s. In comparison, the volume of sealed urbanised land the in the Czech Republic is 3.19% from the size of the entire country, which again when compared to 5.07% of urbanised Germany, looks positive. (See EEA data 2006, http://www.eea.europa.eu/data-and-maps/figures/degree-of-soil-sealing-as.)

But all the physical evidence indicates that the land use sustainability matters in the Czech Republic are getting worse. Country has no sustainable land use policy, or land take targets and that only minimal research concerning the land use has been done so far. There is evident urban sprawl, abundant brownfield sites, the natural and farm land take has been rapidly increasing, sealed areas are rising and population is stagnating. When one realises, that the EU average urbanised sealed land % is only 1, 18% and that the Czech Republic is the 10th most urbanised country in Europe (see also Figure 5), one should worry.

Since the adoption of the new Czech Strategic Framework for Sustainable Development in 2009, the "urban land" has become an issue. Strategic framework has introduced a sole indicator related to land use. This indicator is based on comparing the size of an administrative and the urbanised areas of communities, hence it cannot give a fully comprehensive comparison. So far there are no figures available for regional or local land conversions differences and there is little historic data evaluation to indicate trends. See table 1 for some of the historical data, which shows, that from 1930 until 1999 built-up area per inhabitant has nearly doubled in the Czech Republic. Such an increase is not all down to better living standards; it is mostly an expression of unsustainable land use. Since 1999, the trend of unsustainable land use practises has been visibly rising, peaking in 2008.

Table 1: Historic figures of “built- up” areas (cadastral category) demonstrating doubling the land conversion in Czech Republic last century,

Year	Inhabitants ČR	Built up area (ha)	Built up area/person/m2	% built up area. to size of CZ
1930	10 674 388	74 682	69,96	0,9470
1950	8 896 133	85 854	96,51	1,0887
1970	9 807 697	112 564	114,77	1,4274
1991	10 022 150	126 636	122,92	1,6058
1999	10 278 098	130 102	126,58	1,6498

Source: M.Říha, article Anarchy of urbanism in Czech Countryside,2001

3 UNSUSTAINABLE LAND USE DRIVERS

3.1 *First line of text or heading*

Countries, regions and local communities all try to create systems and tools to help them to have prosperous, safe and inclusive societies, but some of these aspirations may create unsustainable land uses and have a wider than just local effect. If issues of land use sustainability reach through various levels of governance and spread above individual jurisdictions, then new approaches and tools need to be developed to cope with and to address their main drivers. But there are many drivers, which can affect the land use and its management. The main drivers are outlined in table 2.

Table 2: Main unsustainable land use drivers land management and their effects and causes

Driver	Manifestation	Effect	Causation	Level/scale
Increasing living standards aspirations	increase in personal demand on energy, land , resources, food, environment, est…	increase in spatial standards, increased personal mobility, increase in consumption, increase in energy consumption	education, media and cultural indoctrination	global
Growth	increase of development activities and land use demands	expansion, intensification, sprawl, uncontrolled development	migration, demographic and socio-economical changes	global/ regional
Urban Decline	reduction of development activities, land, shifting of urban economic base elsewhere,	decline of urban life quality rise of crime, increasing social stratification, dilapidation, vacant properties and inner urbanized land	economic cycles, bad social economic policies, bad governance, global economic shifts	local/ regional/ global

Urban shrinking	decrease of population and demise/reduction of existing activities on land	reduction of local social and economic sustainability, brownfields	migration, demographic and socio-economical changes	regional
Migration	strong demand on incoming new population	slums, overcrowding, urban quality lowering, multiculturalism, younger population	personal economic betterment, political persecution	global/ local
Sealing	increase in hard developed and impermeable areas	water regime changes, increased flooding	growth or/and bad planning	local
Sprawl	mostly single use/age group/ social group development, along the transport routes	predominantly car use orientate, lucking public infrastructure	bad planning/societal changes	local/ regional
Brownfields	underused, empty, unmaintained properties	decrease of properties market value and reuse potential, pushes the able individuals and organization out of the location, worsening economy and quality of public services	socio-economical changes or/and bad strategic and spatial planning	local/ regional
Contamination of land	risks to human health, animals and bio-tops	soil pollution, surface and land water pollution, inhibits certain land uses	insufficient legal framework, changing environmental standards	local
Erosion	land surface loses its quality	degraded natural and agricultural land,	bad environmental practices and land management	local/ regional/ global

4 SUSTAINABLE LAND USE MANAGEMENT

4.1 *Defining and describing land management*

Land management in the Czech Republic has been mainly related to land consolidation, state property management, land remediation and improvements in cadastral data and their visualisation. Activities that contain land management however, are many. This is the project LAMA description of land management (http://www.la-ma.cz):

a) Land Management covers activities based on managing human-environmental interactions.

b) The activities have different kinds of interactions. The interaction could result in social, economic, cultural, legal, institutional, environmental or political questions. These questions are then tasks for land management.
c) People use land. This is a simple sentence but a difficult task for mankind. Land use management in ecological way (or Environmental Land Use Management) is one of the terms in Land Management.
d) Management involves communication of people and institutions. They have specific roles and positions depending on an actual case.

From this description a definition for Sustainable Land Use Management is compiled for the purpose of this paper.

4.2 *Sustainable Land Use Management definition:*

Sustainable Land Use Management are multiple or organisational activities pertaining to land use and soil exploitation, aiming to:

a) optimize benefits to owners/users/public,
b) limit negative effects arising from public or individual actions,
c) reflect, protect and balances environmental values,
d) enable sustainable beneficial use or reuse of urban, rural and natural land.

4.3 *Urban land management categories*

Unfavourable effects of urban development can be mitigated by various urban land management techniques and tools. The most common urban management tool so far is planning. But formal planning outputs in most of the European countries focus primarily on land use distribution, rather than on actual land use management. Also, due to the scale and technicalities of planning systems, it is mainly being procured by technical planning experts. But urban land use management is mainly a question of implementing politically endorsed strategies (sustainable land use for example). The policy implementation is usually a programme or a managed action, carried out by a city or regional managers. For such an implementation action to be successful at the city level, its message needs to be very clearly stated and abstracted from deep layers of technical issues and jargon.

This is why the balancing of urban growth and urban land use options need to focus mainly on the key land use categories, which are relevant to urban land use management. Therefore, in order to support sustainable urban land use management, various existing land uses need to be looked at in a more general way and for simplicity categorised. The key land use management categories most suitable for this purpose are:

a) Greenfield land (not previously urbanised land designated in planning documents for development)
b) Brownfield land (previously urbanised land suitable for reuse or redevelopment (brownfields are not often identified in panning documents, because brownfields occurrence/disappearance is so volatile that it often cannot be captured by planning documents)
c) Vacant land (land within the urban context, which use is insufficiently utilised, for example empty land after demolitions, gaps, spare and unused institutional land, ex car parks, vacant yards est... (in the planning documents, such vacant land may be marked as developed or developable land – identifying it as a

separate category, makes it clear being declared that is “developed” land, within urban build up area).

d) Urbanised land suitable for reuse (intensification, decrease or change of the present urban land use defined in planning documents).

Representing these categories in a simplified graphical manner would give the city an immediate and better understanding than any long analytical report or extensive planning information. Such improved understanding can quickly increase the quality of local decision making concerning the land use and can help cities better balance their decisions towards more sustainable land uses. Such a tool, when accessible to the public, can also help to empower public monitoring powers for implementing sustainable land use management.

A tool like this is being developed by the project CircUse http://www.circuse.eu . This tool works with 3 of the indicated categories. Category d) is remaining in the “planning” domain. Improved land use sustainability is the key objective of project CircUse urban land management approach. When expressed in indicators, the improved land use sustainability can for example mean that the percentage of newly developed Greenfields land is reduced, or that the proportion of reused brownfields is increased, or that built-up area per head of population is stabilizing and so on.

More sustainable land uses improve urban economic performance (land use intensification makes infrastructure cost cheaper, for example) and therefore can make communities more competitive (saved costs can be invested in improving urban domain quality for example better schools, better public space, better culture etc.)

4.4 *Sustainable land use management scale*

Even a very willing and enlightened local authority cannot deliver land use sustainability by itself, especially if its neighbouring authorities land use decision making is not sustainable. This is why impact of certain land use effects needs to be coordinated from above the local jurisdiction level. Therefore regional/national sustainable land use strategies/policy/plans also need to be implemented. Coordination between various governance levels has to take more strategic focus, which can help to deal with balancing the regional/local growth and managing the declining land uses. In areas faced by serious population decline, specialized regional management practices need to be considered to address sustainable land use and sustainable public services in an integrated manner.

5 EFFECTS OF UNSUSTAINABLE LAND USE PRACTISES

This section addresses the effects of the following unsustainable land use drivers: Urban growth and decline, sealing, urban sprawl and brownfields, mainly to give the main outline of these pressing issues.

5.1 *Urban Growth & Decline & Shrinking*

Urban growth and decline have loca/regional effects and spatial distribution - some urban areas are expanding, others are declining and shrinking. Expanding areas are creating pressures for newly urbanised land. In declinig and shrinking locations demand for already urbanised land is reducing, but demand for newly urbanised land may still be present. Figure 3 ilustrates this effect within the whole European area. Figure 4 illustrates the increasing land use unsustainability in Saxony.

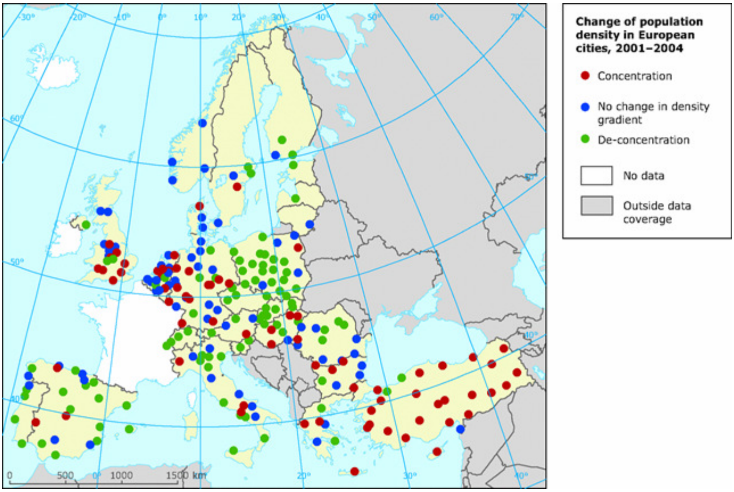

Figure 3: Changes in population and population density in European city regions, 2001–2004
Source: *http://www.eea.europa.eu/data-and-maps/figures/changes-in-population-and-population*

Since the mid 1950s European cities have expanded on average by 78 %, whereas the population of Europe have grown only by 33 % = outcome: urban sustainability and economic land use effectiveness were therefore very substantially reduced. (Source: www.plurer.net). In the majority of European countries urban growth is not driven by population increases. It is mostly driven by increasing spatial demands of stagnating or even reducing and aging populations. This type of urban growth is wasteful and in the long term economically unsustainable and unaffordable

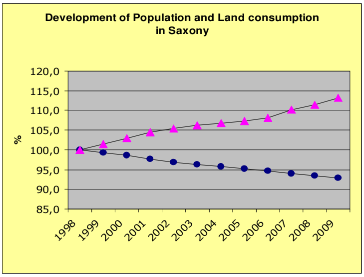

Figure 4: Opening land use sustainability scissors in Saxony, S*ource: Saxony Ministry of Envionm.*

5.2 *Urban land soil sealing – why soil sealing matters and how to cope with soil sealing*

Soil sealing affects ecosystem services and the quality of life in a city. Another climate-related effect of soil sealing is the reduction of the water infiltration potential of the soil, which increases the run-off of water and the risk of river floods. From a global perspective, a low soil sealing per inhabitant reduces the overall ecological footprint. Living in urban areas can provide such a setting. Nevertheless, a high compactness and soil sealing of cities can have negative impacts on the quality of life in such a city. Cities therefore need a smart urban design aiming to reduce soil sealing where it is not necessary - parts of public places, parking lots, paved areas, brownfields etc need to have permeable surfacing, allowing infiltration and water retention. Cities also need to maximize the unsealed and green areas as well as further green elements like street trees, green walls and green roofs, while maintaining their compactness and urban density. When new sealing has to take place, compensation measures should be demanded to undo existing sealing, for example on land which have lost its urban use. See figure 5 for the European area data on land sealing.

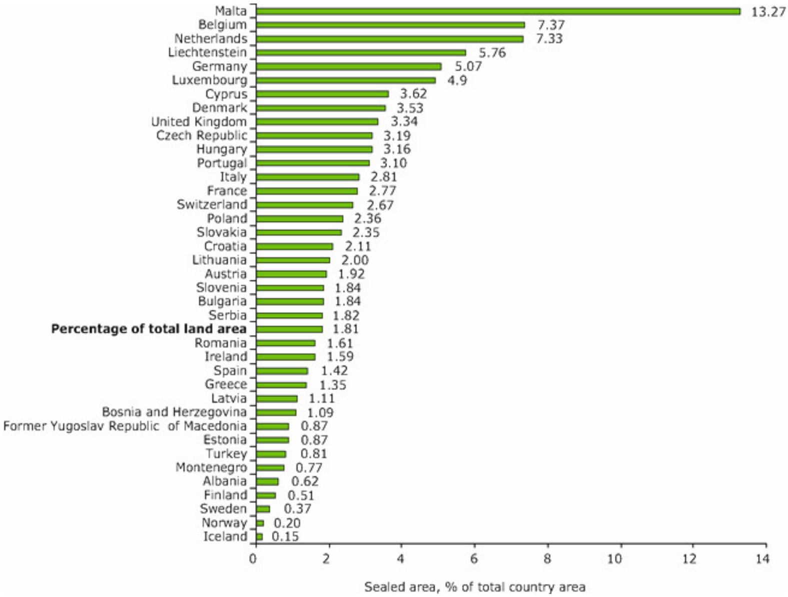

Figure 5: Degree of soil sealing, as a percentage of land area 2006 in the European area, *Source:* *http://www.eea.europa.eu/data-and-maps/figures/degree-of-soil-sealing-as*

In the Czech Republic land sealing is not stressed directly in planning or other policies, but it is often reflected in planning decisions, especially in connection with land drainage techniques. The EEA data shows that the level of sealing in the Czech Republic is fairly high. So far no system of compensation measures for new land sealing exists in the Czech Republic.

5.3 *Urban Sprawl*

Urban sprawl is one of the outcomes of unsustainable land uses. The research project PLUER http://www.pluer.eu sees several unfavorable and unsustainable effects of urban sprawl. These are:

a) consumption of land, loss of agricultural land and open space,

b) destruction of biotopes and fragmentation of ecosystems,
c) higher cost of public services, especially transport,
d) Increase of the use of private car, traffic congestion.
e) Increase in fuel consumption and air pollution.
f) Decay of downtown areas.
g) Social segregation and reduction of social interaction.
h) Poor access to services for those with limited mobility.

Addressing urban sprawl in higly decentralised countries with strong politically and economically independed local authorities is proving exeedingly difficult, even if quantitative policy targets and massive research from the national level are present. (For example Germany is failing to deliver their unurbanised land take targets - land take reduction slowing down to 30Ha/day by 2020). In the case of the Czech Republic, no land take reduction targets exist as yet and the present National Spatial Policy more or less ignors urban sprawl and the natural or agricultual land take as well.

5.4 *Brownfields*

Brownfields have a strong spatial and economic context - under-utilized brownfields sites bring communities reduced or no income and lower their urban land economic performance. A practical approach to redeveloping brownfields is a hallmark of all the remediation efforts. In the Czech Republic the strongest driver to brownfields reuse is usually the economic value of the land. Where the economic value of the land cannot be utilized, brownfields remain brownfields, especially if planning and other documents (fiscal, economical or regulatory) do not introduce positive brownfield reuse measures.

Brownfield projects are also very sensitive to market conditions. During the growth periods, brownfields project are starting later and their attraction for investors sees just after market peaking. The down market periods are very cruelled to brownfields redevelopment and reuse. Investors´ interest in brownfields projects virtually ceases. But one has to be aware that there are situations, where the market is so low (or reuse risks are so high) that no level of public or private efforts can make a material difference to their reuse. Also some brownfields are just too large in their market context and a local solution alone cannot address their remediation.

6 SUSTAINABLE LAND USE MANAGEMENT

6.1 *CZ focus on the unsustainable land*

During the last 20 years the Czech Republic has achieved considerable progress in establishing some aspects of land management in a context of policy, tools, legal framework. Some of the land management issues such as land consolidation or brownfield

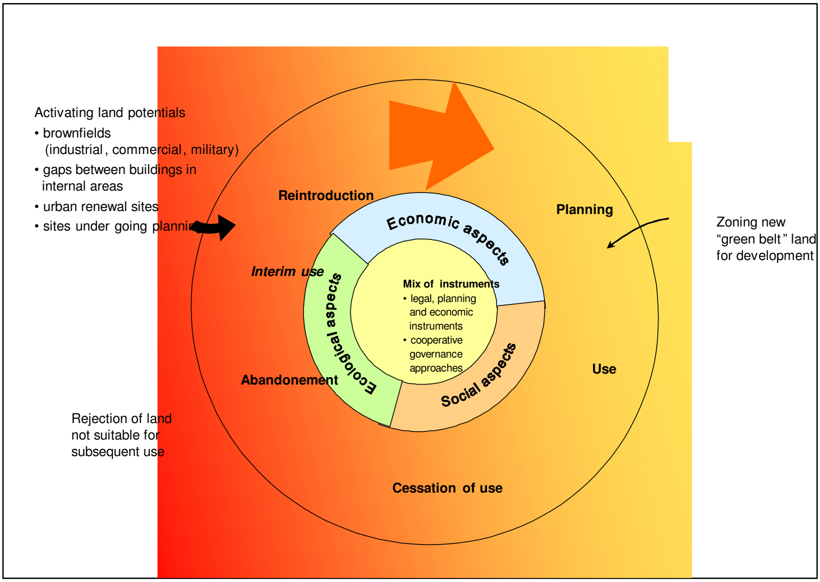

Figure 6: Principles of the circular land use management, *Source: DIFU and project CircUse,*

land are now strongly embedded in national, regional and local policies and strategies. The legal framework was amended to allow for the state property interests to be represented, agricultural land protection law was passed, agricultural land consolidated measures are being implemented and specific land use information is compiled to support local planning systems. What is however still missing is the Sustainable Urban Land Use Management as a strategic tool supporting the delivery of sustainable local/regional development. Not all of the main drivers, affecting the sustainable land use, are addressed evenly in the Czech Republic. The urban growth is covered well by the legal, policy/strategies and programs. The brownfields issue is well advanced and the sprawl issue is emerging. But the shrinking and sealing is not yet addressed or fully identified as driver of unsustainable land use.

6.2 *Project CircUse solution*

Project CircUse advocates an integrative policy and governance approach to sustainable land use, which presupposes a changed land use philosophy with regard to land utilization - this modified land use philosophy can be expressed with the slogan:

"AVOID – RECYCLE – COMPENSATE".

The entire land use cycle, from planning to utilization, disuse, dereliction, building and land recovery forms the core of the strategy. The ultimate aim is dynamic site preservation. In an ideal scenario, this vision would be realized if only land, which is currently in use, was utilized for new settlement initiatives. However, zoning small areas of new land for development is not categorically ruled out, assuming abandoned sites are being reused in other areas (see figure 6 for further explanation).

6.3 *Urban land recycling*

Recycling based principles are commonplace in areas of materials, waste or water management. Such material cycles should serve as models for circular land use management. “Circular land use management” should therefore become an established policy in sustainable land utilization.

7 CONCLUSION

Natural and agricultural land is a limited resource producing a whole range of free and paid for services and benefits which all support human life. This is why un-urbanised land needs to be protected and the already urbanised land needs to be reused and recycled in preference to Greenfields development. But to channel developments onto the already urbanised land, the public sector has to prepare sufficiently conducing conditions, which can motivate to realise developments mainly on already urbanised land.

Sustainable land use management principles need therefore be introduced down to local level, where the key decisions about land use are made. But the realization that land conversions from farm and natural land are a serious sustainability “issue” has at the same time to penetrate also into the national policies.

But the whole issue of the land use sustainability needs also to be understood by the public. The public has to be made aware, how costly and damaging unsustainable land use practises are, and what risks and societal costs they represent.

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Title: Sustainable Construction

Editor: Prof. Ing. Ivan Vaníček, DrSc.

Reviewer: Doc. Ing. Kamila Weiglová, CSc.
Ing. Richard Barvínek

Publisher: Czech Technical University in Prague
Number of pages: 163
Circulation: 300
Edition: 1

ISBN 978-80-01-04873-3