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Application of Spatial Mobility Research as a Tool for Site Planning on a Micro-Regional Level

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ABSTRACT: Spatial mobility research on a micro-regional and sub-regional level represents a strong tool for transport planning allowing flexible and effective reaction to the transport needs of citizens. This article deals with the methodologies of the implementation of spatial mobility research on a municipal level (municipalities and city districts) and the options of using the results for regional development needs. Untraditionally the main emphasis is not on the central metropolitan regions but rather on the contrary, on the rural areas where the principal factor to be focused on is not smooth traffic, but the accessibility of all places. This factor is connected with the risk of social exclusion of the less mobile country inhabitants resulting in a decrease in their quality of life. A well performed spatial mobility research on the micro-regional to sub-regional level may function as a traffic SWOT analysis, though, pointing out risks connected with the mobility of the population and revealing opportunities for regional development stimulation.

KEY WORDS: Transport geography, transport sociology, quality of life, spatial mobility research, public transport.

1 INTRODUCTION

Economic growth, accompanied by the increasing living standards of the population, is inseparably connected with an increased demand on the transport network capacity, caused, among other things, by the growing mobility of the population. The options for increased effectiveness of transport network planning include monitoring (as far as permitted by the law) the mobility of the population for current transport performance mapping. Transport performance may be analysed either indirectly, by means of a transport census, or directly by means of spatial mobility research. The inputs from transport census provide valuable quantitative data thanks to which it is possible to apply geographic modelling to the creation of relatively realistic development models. This information is sufficient from a technical point of view. On the other hand, what also needs mapping are the reasons for certain transport-related behaviour of the population and the related social changes which may also reflect to a significant extent in future development. These qualitative data on transport-related behaviour of the population, which may in addition be used as a data basis for corrective measures, may only be obtained through the observation of spatial mobility of the citizens.

Spatial mobility can be defined from the viewpoint of transport geography and sociology of transport as a process of movement of persons in time and space with the attributes of a poly-dimensional nature, including data on movement in time and space, on motivation for the movement (attractor data), on motivation for route selection (data on the transport network), qualitative data (type of transport), and various complementary data (subjective assessment of the process by the respondent, etc.). On the basis of the motivation spatial mobility can be divided into two types, forced, i.e. mobility for the reason of the necessity of sustenance, or other liabilities, and voluntary, i.e. mobility as the choice of the respondent, purely based on factors not related to basic sustenance. While at least gross data on forced mobility, represented mainly by commuting to work, may be obtained from national censuses – in the Czech Republic from the Census of Population, Houses and Apartments (the latest performed by the Czech Statistical Office in 2001), voluntary mobility informing about the lifestyle of the population and the related living standards cannot be mapped by mere censuses, and therefore more advanced research methods need to be found.

2 SPATIAL MOBILITY RESEARCH

Responses to the calls for more extensive data on the transport-related behaviour of the population include spatial mobility research, known under the more general term as travel surveys. This research is implemented in various forms in some advanced countries of the world (UK, Germany, the Netherlands, the U.S.A., New Zealand, and others). With regard to the scope of the investigation travel surveys can be divided into national surveys, aimed at formulations of more general trends in the transport-related behaviour of the population, and local surveys, monitoring in greater detail city-sized areas and their backgrounds, or micro-regions.

General methods of travel survey implementation include questionnaires for the respondents (individuals, or households). The usual questions cover the socio-economic status of the respondent (age, gender, education, job, etc., or, in the case of households, data on the members living in the household, their number, structure, income, number of cars per household, etc…), his/her car (type, age, brand, average number of passengers per journey, type of drive, fuel consumption, etc…), usual destinations (locality and distance, time demand of the journey, time of the day of the journey, purpose of the journey, usual transport mode, financial demand of the journey, etc…) and routes (motivation for route selection). This questionnaire method is usually combined with a few days (mostly a week or a fortnight) of monitoring of the actual mobility through travel diaries, in which the respondents write details of all journeys during the monitored period – with data on the locality where the journey started, the destination, the route selected, the time of the journey's start and end, the transport mode used, the purpose of the journey, potential other passengers (who travelled with the respondent), etc. The travel diaries are used for overall precision of the spatial mobility data of the population, but are not always required due to the demand placed on the respondents (and the related potentially higher costs of the survey). From a psychological point of view it is sometimes interesting to compare the responses in the questionnaires to the reality recorded in the travel diaries. Sometimes the data, especially on the time demands of the journeys, are biased for different transport modes due to the respondents´ personal preferences.

Even though the data of travel surveys may be very similar in nature, the options of their application vary, depending on the scope covered by the survey (the size of the area covered) and the respondents sample size. As nowhere in the world does the travel survey take the form of census, the options of utilisation of the national survey data are limited by the very fact of the limited number of respondents. Spatial mobility as a theme with a strong geographic dimension certainly deserves research into its spatial differentiation. Unfortunately, in reality only social differentiation may be studied, due to the small numbers of respondents.

3 NATIONAL TRAVEL SURVEYS

Top-quality spatial mobility research on a national level is represented by the British National Travel Survey (Department for Transport, 2009), where the first stage of the research involves face-to-face contacts with the households, while the second stage is covered by seven-day travel diaries with all members of the households. In 2007 the survey addressed 15,048 households. The even distribution of the addresses allowed for the territory of UK to be divided into 684 territorial units for this purpose (PSU – primary sampling units) where the addresses were evenly generated (National Centre for Social Research, 2008). The survey is performed on a yearly basis.

A relatively long tradition since 1985 has been enjoyed by the annual Dutch National Travel Survey (SWOV, 2009). Unlike the British survey the time of monitoring the respondents is shorter – 1 day – and includes a travel diary followed by an inquiry. This survey also covers the transport-related behaviour of households. The respondents are interviewed in groups by phone and e-mail, with the main emphasis laid on motivation of the respondents to cooperate (this method was adopted in 1999 in reaction to the continuously decreasing response to the inquiry). The Dutch have in fact taken over the German model New KONTIV® Design (Socialdata, 2006), which has also been used in Germany, but not on a national level and only in selected areas such as urban agglomerations (Socialdata, 2009).

Examples of surveys with a longer than annual periodicity include the American National Household Travel Survey (RITA, 2009). This survey has so far been held in 1969, 1977, 1983, 1990, 1995 and 2001-2002, with the periodicity of roughly 7 years. The most successful survey was performed in 1995 when about 68 thousand of the total number of 80 thousand addressed households responded to the inquiry. The main problem of the American surveys is their lack of homogeneity, though. While some have been based on personal visits to the respondents, others have involved phone communication. The travel diary was first used in 1995. In addition, in the past there were two different types of spatial mobility research, including the Nationwide Personal Travel Survey (NPTS) and the American Travel Survey (ATS) (see the Bureau of Transportation Statistics, 2004). Not only due to the research methodology, but also due to the absence of internationally recognised standards, incomparability of the data is an issue affecting not only the Americans, but also the Europeans, and international comparisons are therefore quite exceptional.

High-standard spatial mobility research from outside of Europe includes, for example, the annual New Zealand Ongoing Household Travel Survey (New Zealand Ministry of Transport, 2009), addressing about 2,800 households a year. The form of the survey is again the face-to-face interview, and a two-day travel diary. The most exotic localities where the spatial mobility research has ever been performed include the Republic of South Africa, where in 2003 the National Household Travel Survey (South African Department of Transport, 2007) covered a sample of 45 thousand households.

4 LOCAL SPATIAL MOBILITY RESEARCH

While the aim of the national travel surveys is to obtain general information about the transport-related behaviour of the population and quantify it, the regional or municipal travel surveys aim for the provision of concrete data on the situation in the region in question, subsequently used as the basis for transport and site planning. Unlike in the case of national travel surveys, the local research may be more specific, for example, asking about the exact routes of the journeys, or about the selection of the mode of transport for the different sections of the same journey in the case of multimodal transport use (such as the combination of walking, train and bus). Local and regional spatial mobility research, with its level of detail and diligence, may even perform the role of a case study. Of course the final structure of the implemented regional travel surveys always depends on the requirements of the client and so this is not always the case, unfortunately.

Research into the transport-related behaviour of citizens of large cities and urban regions prevails absolutely among the implemented regional travel surveys. This is more than logical – knowledge of transport-related behaviour of the citizens is most valuable where there are transport issues to be resolved, i.e. in the overpopulated metropolitan regions (see Schmeidler, 2008). Spatial mobility surveys in these areas supply data on locality and significance of the attractors, which, in combination with a socio-demographic projection of population number development in the individual parts of the city or region, represents a relatively good basis for road capacity and route planning within the area. A good example of these surveys may be the abovementioned German cities (Socialdata, 2009), the Australian metropolitan areas – Sydney (New South Wales Ministry of Transport, 2009) and Brisbane (Queensland Travel, 2008), the London Travel Demand Survey (Transport for London, 2008), or the Household Travel Survey in Washington (MWCOG, 2009).

In the rural areas and in the peripheral regions traffic collapses due to excessive travel are quite rare and therefore there are virtually no spatial mobility surveys performed in rural regions, for the main clients demanding travel surveys are transport planning offices. However, travel surveys provide information so complex that they may be used not only by urban planners and transport engineers but also by psychologists, sociologists and geographers (see Drápela, 2008). It is because the transport-related behaviour trends are affected by a number of different factors, and therefore multidisciplinary research is justified here. Spatial mobility research in peripheral rural regions is most needed, though, as the transport-related behaviour of the local population is much different from the behaviour of city populations, and the nationwide research provides for no details. The main purpose of the research would need to be changed for the rural regions, though, for while this type of survey in the urban regions usually serves the need for the development of a concept of spatial and functional layout of transport infrastructure, in the rural regions the main focus should be the creation of a concept of utilisation of the transport infrastructure as the backbone structure of regional development.

5 SPATIAL MOBILITY RESEARCH ON A MICRO-REGIONAL AND SUB-REGIONAL LEVEL

Before studying the spatial mobility research on the micro-regional level it needs to be said that the term micro-region means a functional nodal region defined by the range within which people commute to work, by its centre with at least 10 – 15 thousand inhabitants and the background of at least another 10 thousand, i.e. a functional region defined by geographical methods and not a voluntary union of municipalities created for a purpose. The term sub-region then may be defined as any functional region whose centre is smaller than a micro-regional level centre. For a municipality to be considered at least a sub-regional centre there must be some traceable commuting to work or to school or to services in the centre from the surrounding villages.

The specific motivation for spatial mobility research in regions outside the metropolitan areas must be reflected in the very methodology of the research. This is why the purpose of the research must be clearly defined: In the first place the research should focus on the spatial localisation of the local attractors activating the need for travel in the local population, completed with qualitative information about the types of attractors, and further research into the issue of the level of utilisation of public transport means and a comparison of the offer to the demand. And last, but not least, the subject of the research should include a critical assessment of population mobility aimed at discovering the barriers restricting it. As for the forms and methods of the research, the inquiry may certainly want to be complemented with travel diaries confirming or denying the generalisations drawn from the questionnaires, but the need for the latter research form is not so urgent in the rural regions (in the urban environment the road density is higher and thus the travel diaries follow the exact attributes of the journeys, such as the route and the timing, which in the rural areas, regarding the thin road network and the exceptionality of traffic collapses and congestions is information which is quite easy to estimate relatively accurately), and the costs incurred may not bring information with substantial added value in comparison to the questionnaire, unlike in the cities. In addition the questionnaire may partly substitute the travel diary, if the questions are adequately posed.

Why	Where	How	How long	How often	How much	Which way	Dist.
To work	Pelhřimov	A	20 min.	2T	CZK 20	130, 112	20 km
To school							
For daily shopping	Pelhřimov Kaufl. Lidl	A	20 min.	2T	CZK 40	130, 112	20 km
	Senožaty Flop	P	5 min.	1T	CZK 0	p	500 m
	Humpolec Billa	A/B	12/20 min.	2M	CZK 26/20	130, m	13 km
For special shopping	Pelhřimov centre	A	20 min.	1T	CZK 40	130, 112	20 km
	Humpolec centre	A/B	12/20 min.	1M	CZK 26/20	130, m	13 km
	Arneštovice butcher	A	8 min.	2M	CZK 16	130, m, 129	8 km
	Hořice ZD	A	6 min.	2M	CZK 10	m	5 km
For services	Pelhřimov	A	20 min.	2M	CZK 40	130, 112	20 km
	Humpolec	A/B	12/20 min.	2M	CZK 26/20	130, m	13 km
To cultural or social events	Pelhřimov music club	A	20 min.	2M	CZK 10	130, 112	20 km
	Senožaty pub	P	6 min.	2T	CZK 0	p	600 m
	Humpolec	A	12 min.	1M	CZK 26	130, m	13 km
For leisure time activities	Senožaty tennis courts	P	6 min.	1M	CZK 0	p	600 m
	Senožaty football ground	P	2 min.	2M	CZK 0	p	200 m
To visit friends	Jihlava	A	40 min.	1M	CZK 80	130, m, 523	40 km
	Žďár n. S.	A	60 min.	1M	CZK 140	130, m, 34, 150	70 km
To offices							
Other	Želiv swimming pool	A	10 min.	S	CZK 20	130, 129	10 km

Figure 1: Example of mobility attractor identification with questionnaire: For a description, see the body of the article

Identification of attractors is the first stage of the socio-geographical survey of spatial mobility. Location and nature of the attractors represent the principal factors forming the transport-related behaviour of the local population, and that is why they require maximum attention. Attractors must be categorised first and then provided with attributes, such as location, distance from the place of residence, usual transport mode used to reach the attractor, the usual time spent on the way, and the frequency of this activity. Additional attributes may also include the financial demands of the journey. In practice this means that the respondent needs to be asked how, where, how long, how often and for what cost he or she commutes to work/school/shopping centre, etc. Figure 1 shows a draft questionnaire focusing on the identification of attractors, including an example of how such a questionnaire is to be filled out. It needs to be said, though, that in reality the questionnaires are only filled out with indicator values and figures or letters standing for the individual variants. For the purpose of this article the more descriptive variant that follows was selected.

Column 1 lists the basic attractor types while column 2 lists the individual attractors. To leave out attractors which have a small or negligible effect (such as a social event held in the municipality once a year, etc.), it is recommended to start the whole section with the question "Do you travel at least once a month to…" Where the event is important for the season it certainly must be included (see Fig. 1, row: Other). The column on the mode of transport includes letters with the following meaning: A = automobile, B = bus, P = walking, where more modes are used the individual letters are separate with slashes. The letters used in the "how often" column bear the following meaning: T = weekly, M = monthly, S = once a season, 1 = once and 2 = more often than once. In the route column the numbers represent road identification, p = foot paths and m = local roads. This is obviously an insufficient division; in reality the local roads would need some working numbering for the information to be complete. The last column shows the price of the transport – in reality the respondent is obviously unable to specify the price of the journey without a long calculation, especially in the case of private cars. This is why the inquirer asks about the mean fuel consumption of the respondent's car, which most respondents are able to specify more easily. About the evaluation of the part of questionnaire shown in Figure 1 - the questionnaire has been filled out by a resident of Senožaty, in the micro-region of Humpolec, who commutes to work to the more distant Pelhřimov. There he also does most of his shopping, with a preference for supermarkets along the way home. The respondent travels to work by private car with another passenger sharing the travel costs. In comparison to public transport, which is considerably slower and also more expensive in this situation, the respondent shows a clear preference for his private car. The travels to Humpolec focus on goods and services that cannot be had in Pelhřimov. In this case there is a relatively frequent connection by public transport, which is also partly used by our respondent. A positive fact is that the respondent walks to destinations within his home municipality. For journeys to less significant destinations the respondent again uses his automobile, mainly for the reason of an absolute lack of public transport to the destinations. The respondent therefore shows a strong overall dependence on his automobile. As for the routing, the respondent obviously uses the shortest routes available, most frequently along the local roads, but never along the D1 motorway, a mere 5 km away from his place of residence. The reason is that the motorway toll and the low demand for motorway use on the part of the respondent. Most of his attractors cannot really benefit from travel along the motorway – providing no greater travel comfort to the respondent.

This basic construction of spatial mobility research should be completed for the purpose of regional development with a subjective assessment of the respondents concerning the qualitative characteristics of the regional transport infrastructure. The most important factor should be the identification of the existing barriers to mobility, on the following three levels: in the case of travelling by passenger car or motorcycle, in the case of travelling by public transport, and in the case of walking or cycling. The question asked for the purpose of the barrier identification should be as follows (or similar): "Are there any locations or factors making your travel by car unpleasant, or even impossible, to a certain destination?" A similar question should then be asked about the public transport and about walking/cycling. The most frequently mentioned barriers to mobility in the case of car travel include poor road practicability in winter, poor condition of the road, hazardous sections of the road, poor routing, and heavy traffic (mostly mentioned by elderly people who have problems with orientation in heavy traffic). In the context of public transport most respondents complain of the small number or non-existence of connections to the individual attractor destinations, inconvenient location of the stops, poor connections between individual sections of the journey, and seniors criticise the physical demands of travelling by public transport, caused by the absence of benches at the stops, long waiting times, etc. Identification of barriers to walking or cycling is valuable information for the local councils, for the barriers are mostly represented by hazardous footpath sections within the municipality, not between the municipalities. Sometimes these are also critised, though, for example when the respondent walks to work to the neighbouring village, or to a bus stop to a larger village nearby, etc. The barrier information should be accompanied with data on their location, type and nature. An example of this (simplified) GIS information can be seen in Figure 2.

Figure 2: Example of mobility scheme for 1 inh. – line thickness presents journey frequency, black circles present limiting barriers, grey squares present inconvenient barriers

The most important issues from a regional development point of view include timing and routing of public transport lines. A conveniently organised system increases the accessibility of the individual municipalities and localities, reduces the traffic load of centres and increases the profit of the latter. Public transport is a financially demanding part of municipal budgets, which is why the relevance of every connection has to be carefully considered. The attractor data may serve as basic information for this purpose. These should, however, be completed with information about the demand for public transport, for this demand sometimes does not relate to the actual mobility behaviour of the respondents. The public transport demand should include three attributes: the time when the respondent wants to travel, the destination the respondent wants to reach and the reason why the respondent wants or needs to travel. The summary of the results of these three pillars of spatial mobility research may provide quite extensive information about both the transport-related behaviour of the population and the mobility of the population. These data may then be used as information about the effect of transport on the quality of life of these citizens. The interpretation of the results remains the responsibility of the researcher. Attention should be paid to the identification of the reasons of population mobility preferences, to the ways of improving the accessibility of certain localities and the harmonisation of the public transport timetables, to the utilisation of the current attractiveness of certain areas for their further development or the utilisation of the development potential of the adjacent areas, and to identify and realistically assess the threats resulting from the factors manifesting themselves as mobility barriers.

6 CONCLUSION

Spatial mobility research, however, cannot and should not be the main research method for the development of regional development strategies, even though they may bring useful information at a moderate research cost. The principal advantage of spatial mobility research over the standard SWOT analysis, for example, is the relationship to the real preferences of the inhabitants and their actual problems. The results, therefore, do not represent impersonal proclamations and conclusions, but particular measures addressing particular facts. As is the case when using any soft method, a critical detachment from the respondents has to be kept, however fitting their reflections of the local situations may be. With the spatial mobility research marginalisation of certain areas with poor accessibility by transport or with little attractiveness their resulting decline may be prevented.

Spatial mobility research as a tool for site planning has been successfully tested in COST C27[1] project in Senožaty and Litenčice subregions in 2008. Altogether, questionnaires were filled in by 100 respondents. Besides the low use of the D1 motorway in the Senožaty region, the most interesting fact revealed was a commuting shift in the Litenčice region from the Bučovice area to the Kroměříž area due to frequent closures of I/50 road.

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Evaluation of the Complex Modulus of Asphalt Mixes

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ABSTRACT: The objective of this paper is to evaluate uniaxial loadings in compression for selected asphalt concretes. Cylindrical specimens were subjected to sinusoidal stresses at given frequencies and temperatures. The methodology of the test is discussed and a comparison is made between non-destructive indirect tensile testing and cyclic loading. The findings show that correlations can be made between these two methods.

KEY WORDS: Asphalt mixes, cylindrical specimens, uniaxial loading, frequency sweep.

1 INTRODUCTION

There are several methods for evaluating the performance properties of asphalt concretes. Although theories of such composite material have been well-known since the mid 1960s (eg. Monismith 1961, Sayegh 1965), only a few research centers worldwide carried out practical investigations of viscoelastic theories within the following two decades. Most of the reasons for this were rather practical. In order to observe real properties, the stress-to-strain ratio needs to be recorded at very short loading times and at various temperatures and sophisticated equipment is needed. The situation changed after the Superpave Performance Prediction system was introduced in the United States (Superpave, 1996). Nevertheless, it took several years for the Superpave System to be accepted at a national level and for new guidelines for asphalt concrete, based on performance testing, to be created by the National Cooperative Highway Research Program (NCHRP 465, 2002). These efforts led to the Mechanistic-Empirical Design Guide for New and Rehabilitated Pavement Structures (NCHRP 1-37A, 2004). The Guide, which is currently being evaluated by many state highway agencies, employs mechanistic-empirical approaches, where uniaxial / triaxial cyclic loading serves as an important input into pavement design and prediction models. This test replaced previously used diametral test procedure, indirect tension test (NCHRP,1997).

Some of the findings have been used in European standards (EN 12 697-26, 2008), but the evaluation of uniaxial testing in compression has not been as successfully adopted by European agencies as, for example, the indirect tension test. This will lead to proper pavement thickness designs for a given period. Following such an approach, long-life pavements can be created on the basis of rational design with an optimized life-cycle cost.

2 EXPERIMENTAL GOAL

In this study, the goal of the experimental plan was to apply unconfined cyclic loading with a diverse range of frequencies at various temperatures and in various magnitudes to selected mixtures. Also, appropriate response parameters that correlated most highly with the indirect tension test were taken into consideration. A comparison of moduli was done on Stone Mastic Asphalt (SMA).

2.1 Material used

Asphalt mixes with local bitumen and aggregates were selected for evaluation. Mixes, used as a surface and a binder course denoted as Stone Mastic Asphalt (SMA) SMA 11S is characterized as premium mix for road construction, table 1. Typically, such materials show good rutting resistance and a high stiffness modulus.

Table 1: SMA11S, gradation table, passing limits, mix properties

SMA 11S		Gradation limits	
sieve size	passing	min. passing	max. passing
(mm)	(percent)	(percent)	(percent)
11	91.0	90	100
8	50.0	45.0	60.0
4	28.0	26.0	38.0
2	22.0	20.0	28.0
0.125	13.0	9.0	15.0
0.09	10.0	8.0	12.0
Binder content (percent)			6.2
Air voids (percent)			3.2

2.2 Specimen preparation

All specimens were prepared under the same procedure. The asphalt binder was mixed with the aggregate skeleton according to the design charts listed in paragraph 2.1. Different mixing temperatures were based on the viscosities of the bitumen. A rolling wheel compactor was used for slab preparation. The amount of material needed was calculated using mold dimensions, the bulk and maximum specific gravities of the mix and the necessary target air voids. The height of the compacted slabs was set to 160 mm. Two specimens were cored from each slab, as depicted in Figure 1, after cooling. The diameter of the cored specimens was 100 mm. The edges were trimmed in order to achieve perpendicular planes for sinusoidal loadings.

The specimens for the indirect tension test were cut from the specimen, which had already been subjected to cyclic loading. This technique enables us to evaluate the same material under different loading conditions.

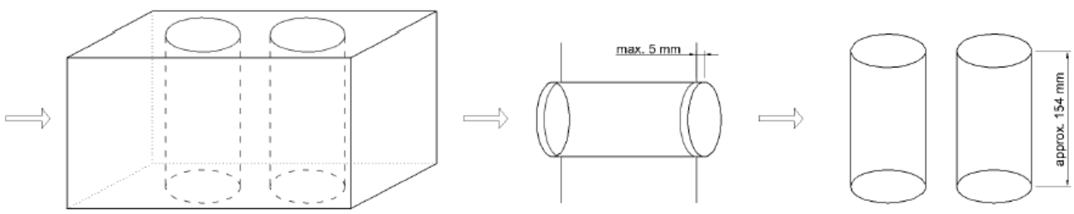

Figure 1: Procedure for specimen preparation (Bošek, 2010)

2.3 Cyclic modulus testing procedure

Since this methodology is not well defined under the European standards, a modified AASHTO procedure was applied (AASHTO, 2004). The specimen was placed inside the loading apparatus (Figure 2) and was subjected to a series of stresses at different frequencies and temperatures (Figure 3). The applied load was adjusted for each temperature to achieve strain levels in order to capture linear viscoelastic behavior. The strain level was adjusted on the basis of experience and the stress response of the specimen between 50 and 150 μS.

The procedures for cyclic modulus can be summarized in the following steps:

- Prior to the test, four metal gage points were glued by epoxy to each specimen.
- Two LVDT extensometers were mounted on the specimen to capture the horizontal deformations measured on each side of the specimen.
- The test specimen was placed in the load frame. A seating load of five percent of the total load was applied to the test specimen to ensure proper contact of the upper loading head.
- The specimen was loaded by applying a repeated and continuous uniaxial sinusoidal load to obtain horizontal strains in the viscoelastic range.
- While loading, the computer software recorded all important characteristics as stress and strain sine waves in the time domain, calculating the modulus and other parameters.

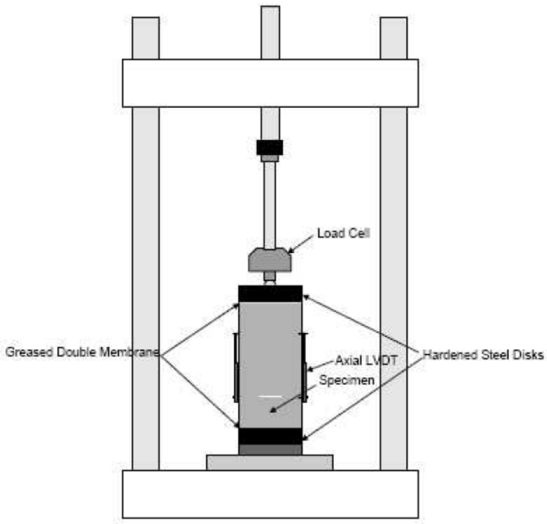

Figure 2: The cyclic loading scheme (AASHTO, 2004)

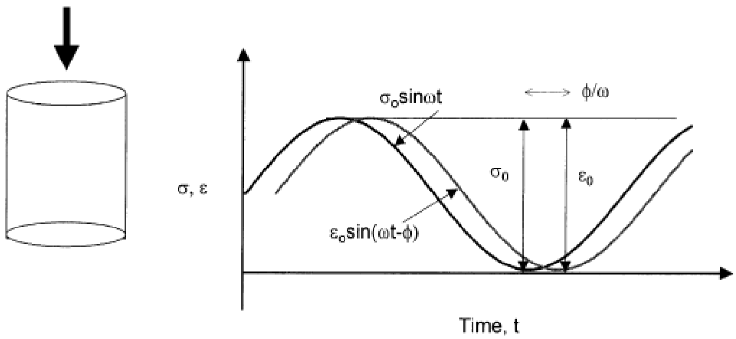

Figure 3: The principle of the stress – strain relationship (NCHRP 465, 2002)

2.4 Indirect tension test description

The methodology for the indirect tension test is well established in Europe, thanks to the design devised at the University of Nottingham (Cooper & Brown,1989), known as the Nottingham Asphalt Tester (NAT). Due to its simplicity, asphalt producers could easily and cheaply carry out their own tests and immediately see how their materials behaved in relation to others. This has led to a revolution in the asphalt industry, and NAT was later adapted by British standards (BS DD 213,1993) as well as European standards (EN 12 697-26, 2008). It is used regularly, evaluating materials in existing pavements. It has been used extensively in estimating the potential of various mixtures and binders, and serves as a tool in pavement design methodology (TP170, 2004).

The procedure is straightforward: a cylindrical specimen is placed under the loading frame and, while loaded, two vertical transducers measure the deflection on each side, created by stress, denoted as $\sigma_{x\max}$. The adjusted stiffness is calculated from five loading pulses, Figure 4.

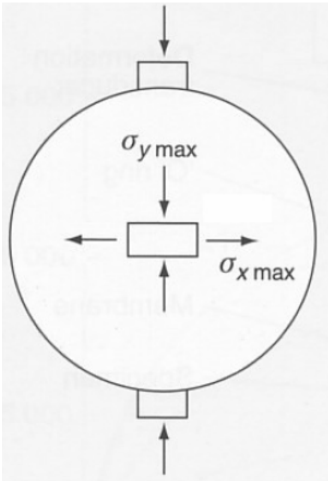

Figure 4: Schematic uniaxial loading in the indirect tension test

3 RESULTS

The stress-to-strain relationship under continuous sinusoidal loading for linear viscoelastic materials is defined by a complex number called the "complex modulus" (*E**). The absolute value of the complex modulus, |*E**|, is defined as the cyclic modulus (dynamic modulus in the USA). The modulus is mathematically defined as the maximum (i.e., peak) dynamic stress (σ_o) divided by the peak recoverable axial strain (ε_o).

$$|E*| = \frac{\sigma_o}{\varepsilon_o}$$

On the other hand, the indirect tensile test has been used successfully to measure the stiffness modulus of asphalt concrete mixtures. The critical stress location by load is generally considered to be at the bottom of the asphalt concrete layer and immediately underneath the load, where the stress state is the longitudinal and transverse tension combined with vertical compression. The stress state in the vicinity of the center of the face of an indirect tension specimen is very similar to this stress state. Consequently, the complex modulus obtained by the indirect tensile test can also be compared to provide reasonable moduli correlations.

Stiffness $S_m^{'}$, adjusted to a load area factor of 0.60, can be calculated as follows:

$$S_m^{'} = S_m \times (1 - 0.322 \times (\log(S_m) - 1.82) \times (0.60 - k))$$

S_m is the measured stiffness modulus, depending on the applied load, the horizontal deformation measured, the dimensions of the specimens, and Poisson's ratio. Proper determination of such a constant is rather vague for asphalt mixes. It is generally believed that the Poisson values lie between 0.20 and 0.45, according to the temperature. The time of loading however, is not taken into consideration. Other research indicates that the ratio is also a function of the amount of polymers in the asphalt binder (Tech Brief, 2008).

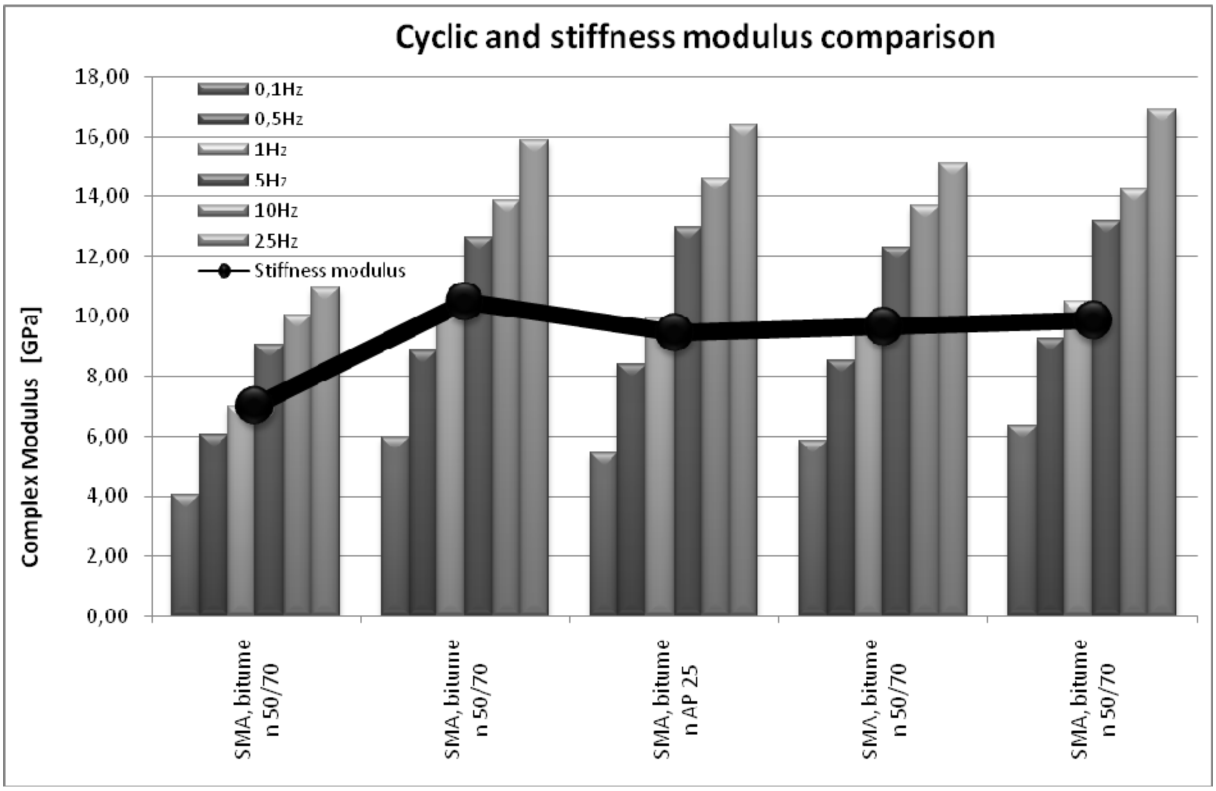

Figure 5: Comparison of complex modulus and stiffness measured by different procedures at 15 °C (Bošek, 2010)

4 CONCLUSIONS

The results from the indirect tensile test indicate that the test is easy to perform and has the advantages of simplicity. However, proper determination of the input characteristics is needed for correct stiffness values. It is not recommended to test materials at temperatures above 30 °C, and also thin specimens, due to the reduced stiffness of the asphalt mixes. This is because the stress differs from the theoretical formula for moduli calculation, while the stress in sample in the compression test is virtually unchanged. In this case, data obtained from the cyclic compression test are more straightforward, showing the real strain, stress - time response. A comparison of the two methods showed that there is a correlation between complex modulus and stiffness on selected asphalt mixes, Figure 5. Corresponding values were exhibited by the same moduli at a frequency of 1 Hz at a temperature of 15 ^{o}C. More research will be done on various mixes and various binders, using the same approach.

ACKNOWLEDGEMENT

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Air Rail Links and Risk Analysis of Prague Airport Project

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ABSTRACT: This paper describes the problems related to the integration of air and railway transport, which require building railway connections to hub airports, especially networks of long distance railways and high-speed tracks that link large cities with airport terminals. It presents and analyzes some solutions that have been implemented in Europe and focuses on a similar project which is currently being prepared in the Czech Republic at the dynamically growing international airport in Prague. For the final decision making process concerning the possibilities of a rail connection between Prague city and its airport a comprehensive comparative study, including risk analysis, was processed by the Czech Technical University in Prague, Faculty of Transportation Sciences.

KEY WORDS: airport, Prague airport, hub airport, airport and railway network, high-speed tracks, intermodal transportation.

1 INTRODUCTION

Present economic and social development in its global dimension creates more and more demands on transport. Transportation is provided by various transport means, each having benefits, as well as disadvantages. Good co-operation and utilization of the advantages of each transport mode in their particular link of the transport chain, where they can provide the most benefit, is the best hope for the future.

Air transport has the strongest position in respect of long distance transportation. Speed is its greatest advantage, although there are also some significant disadvantages. Long-distance air transport is assured though a relatively sparse network of hub airports, construction of which is very demanding from a financial point of view. Modern airports are also very demanding from the viewpoint of space, and, due to their unfavourable influence on the environment and health, are erected mostly on the outskirts of built-up areas. On the other hand, hubs are erected in the areas in which there is an important flow of passengers and goods to be transported by airplanes. This shows that modern airports are intermodal terminals, usually comprising of air, rail and road transport, and, in some cases, even water-borne transport. As the overwhelming majority of passengers start and end their journeys within developed areas, it is necessary to assure appropriate subsequent transport. In respect of servicing big airports, rail tracks particularly come into consideration for connecting the airport and adjacent cities, and, eventually, urban agglomerations, as well as for the transportation covering medium-length distances, when the collection and distribution of passengers is executed from and to neighbouring towns which either do not have their own airports, or where the realization of direct flights would be inefficient or unsuitable for other reasons. The big perspective envisages the harmonization of long-distance air transport and high-speed railway transport within continents.

2 INTERMODAL CONCEPT OF A MODERN AIRPORT

Modern hub airports integrate air transport mainly with long-distance rail transport and, in some cases, water-borne transport. Road network connections are being implemented in all airports. This inter-modal system is built-up in accordance with the principles stated below:

Future economic model of air transport functioning could include:
- Conventional network carriers offering their services in alliances,
- Regional companies (independent or as daughter companies of bigger firms),
- Rental carriers,
- Low-cost airlines.

Where:
- Network carriers will focus on long-distance and intercontinental flights,
- New companies established by these network carriers will constitute "feeders" for long-distance flights, thereby taking over some parts of the low-cost airlines' clientele,
- Regional carriers will supply demand for regional airport services,
- Low-cost airlines will specialize in direct flights,
- Low-cost airlines will compete with companies specialized in flights to order (rental carriers).

The Integration of Air and Railway Transport

To realize the above-mentioned integration of air and railway transport, railway stations are being built mainly at airports in attraction zones, thus enabling the intended cooperation between air transport and railway traffic. Two options are available: either to connect the high-speed railway line directly with the railway station at the respective airport or to interconnect airports with a suburban railroad, or eventually a specialized high-speed railway line (e.g. Heathrow Express in London, etc.).

A possible recommendation could be that the inter-modal product meets the following requirements:
- Guaranty of connections – This means that passengers with an integrated fare ticket have to be sure that they will not be left halfway due to delays,
- Inter-modal portal – This involves a unified source of information for passengers,
- Central marketing – The inter-modal product has to be offered by all participating carriers together,
- Related services at the baggage delivery office. This refers to information on connecting transportation, ticket sales, etc.

As part of the abovementioned integration, several airports currently offer the following services:
- Transport of individuals to the airport by special trains,
- Baggage carriage - DB offers to carry passengers' baggage, which has to be submitted three days prior to departure. In Switzerland, SBB offers baggage carriage from more

than fifty railway stations one-day prior to departure, including customs clearance, while passengers receive their boarding cards at the same time,

- Check-in, checkout – The passenger has the possibility to check-in at other places than the airport (automated machines, phone, fax, web/wap). During the check-in, the passenger receives all necessary travel documents (boarding card, baggage label, baggage tag). The check-out takes place not at the final destination airport but at the final railway station,
- Ticketing – This involves offering a combined travel document: "train ticket - air ticket".
- Information – This refers to the possibility of getting access to important updated information about air transport at places other than only the airport (system Travelnet - Fraport, Infoflyway - Lufthansa, Infoplattform - RMV).

General requirements for inter-modality according to passengers' demands could be formulated as follows:

- Short travel period – This includes an optimization of the actual time of transfer and time spent at the airport. For transcontinental flights, services with a higher level of comfort should be offered,
- Check-in and baggage carriage – If possible, only one check-in with the first carrier to be used by the passenger, and to whom he would submit the baggage. Baggage collection should take place from the last carrier once at the final destination,
- Clearance during the travel,
- Integrated travel document.

In order to implement an intermodal terminal and intermodal transportation product in hub airports it is necessary to assure the connection of airports with the railway network, and namely high-speed train networks, which, in their parameters, come close to air transport parameters. As regards the situation in Europe, there was a survey and overview of subsequent land transport at 65 of the most important European airports undertaken by Jan Perner Transport Faculty University of Pardubice in 2004 (status as of December 31, 2004).

This overview shows:

- 45 airports have rail and other connections
- 6 airports have underground lines (metro) or light suburban rail transport
- 14 airports have only road connections

On the grounds of the abovementioned survey we can also state that there are only four cities with more than 1 million inhabitants having an important airport which is not connected with the city by a rail transport. These are: Marseille, Prague, Warsaw and Budapest. On the other hand, there are also some small airports which have a rail connection (for instance, Dresden, Leipzig-Halle) or where the rail connection is under preparation. When making a decision about an appropriate transport mode, passengers are paying attention more and more to the time spent in transport. This time comprises of several parts which may be split into the main transportation phase (time when the passenger physically moves from one place to another) and secondary transportation phase (period when the passenger does not move anywhere). While in the past the greatest attention was given to the main phase (effort to maximize the speed of transport means etc.), at present there is a trend of an all-embracing focus on the total period of transportation, thereby also including the secondary phase. The so called concept of minimum connecting time is followed.

For the integration of high speed tracks (HST) and air transport, there are two ways of mutual interconnection existing:

- HST goes through a railway station located directly in the area of the airport, within walking distance for airport passengers, eventually accessible by internal airport transport,
- the airport is connected to such a network through a suburban rail line, and eventually through a specialized speed rail (e.g. Heathrow Express in London, etc.).

Service level compatibility must focus on the following aspects:

- an equal offer of intermodal transport services in the sales distribution network, including code sharing (hitherto the privilege of air transport only), check-in down to the final destination, irrespective of the fact whether the transport starts with air mode and ends HST, or vice versa
- global computerized distribution systems should include both air transport and railway segments with no discrimination, i.e., one transport mode cannot be preferred above any other one. These systems must be able to issue both types of travel documents, and must provide for their possible integration
- service staff (ground personnel of the air transport and railway personnel) must master issuance and acceptance of air, as well as railway transportation, documents and their administrative processing (booking and changes in booking, pricing, billing)
- time schedules or shuttle operation of HST connection to the airport must be mutually adjusted.

It seems that Frankfurt airport has made the greatest progress in the creation of an intermodal concept in Europe. Frankfurt airport is considered to be an intermodal transport hub, as the airport passengers have direct access to the long-distance trains of Deutsche Bahn's (German Rail) ICE-train network through the airport railway station. According to the opinion of Fraport AG company, with the further expansion of the European high-speed rail network FRA will be one of the most significant integrated transportation centres on the Continent. The inter-modal system of Frankfurt airport is designated as **AIRail Service.** Operating successfully on the Frankfurt – Stuttgart (since May 2001) and Frankfurt – Cologne (since May 2003) routes, the cooperative AIRail Service ("train to the plane") by Deutsche Lufthansa AG, Deutsche Bahn AG, and Fraport AG, also started serving the Frankfurt – Siegburg/Bonn route at the beginning of November 2007. According to the "seamless travel" principle, travellers pass the check-in at the central train stations to receive the boarding passes for their onward flight from Frankfurt Airport. (At the Stuttgart and Cologne stations, the check-in counters are at the train station; at Siegburg/Bonn, an automatic check-in machine is located at the DB Travel Centre). Upon arrival at FRA's long-distance train station AIRail passengers have to check in their baggage at the LH baggage drop counter in the AIRail Terminal. The AIRail Terminal is located directly adjacent to FRA's long-distance train station. Having baggage check-in and baggage claim directly at the AIRail Terminal significantly contributes to the convenience of passengers making their way through the terminals to and from the aircraft.

The Swiss model allows for the check-in of airport passengers, including their baggage, usually a maximum of 24 hours before departure in more than fifty Swiss railway stations. At the same time, the passenger receives the Boarding Card containing information with the seat which has been allocated to the passenger. Such services allow the passenger to be mobile without baggage a day before departure and to avoid possible waiting for check-in at the airport. The passenger has to present necessary documents for the check-in: airplane ticket for each passenger with OK reservation, possibly an electronic airplane ticket, and passport if a visa is required. This service is provided for flights from Zurich and Geneva operated by 25 companies, and, in fact, for all charter flights from Zurich and Geneva, except for flights to the USA. Detailed information about check-in and transportation of baggage in the system air-rail, as well as precise time schedules for check-in and baggage claim, may be obtained at www.rail.ch/check-in website.

A similar service is also provided to arriving passengers. The baggage of passengers arriving to Switzerland from airports all over the world is delivered directly to the final railway station in Switzerland through the airports of Zurich and Geneva, irrespective of the company the passenger flew with. When arriving at the airport, the baggage is transported in an automated way right down to the final destination railway station. Swiss transfer tickets (sold only abroad) also include the way from the airport or from the boarder to the point of the final destination.

A similar air inter-modal terminal has been built up in CDG airport in Paris and in some other European airports, as well as on other continents.

3 RISK ANALYSIS OF THE PRAGUE AIRPORT PROJECT

3.1 PRAGUE RUZYNE AIRPORT

Prague Ruzyne airport is located in the centre of Europe. In relation to this location it applies for the function of hub with the function of a transfer junction. In the year when the main runway RWY 06/24 was commissioned (1963), one million passengers travelled through the Prague airport. In 2007 this had risen to 12.5 million of them. Although the number of passengers has increased more than twelve times since 1963, the system of runways has remained nearly without any change since that time. As the interest of travellers in Prague and the Czech Republic does not show any signs of ceasing, the airport expects a further growth in number of passengers and airplanes serviced in the future. In 2012 fifteen million passengers are expected to pass the airport gates, and in 2019 the airport plans to exceed the level of twenty million passengers.

Table 1: Number of passengers growth forecast for Prague Ruzyne airport

Traffic		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
PAX	Mil	11,5	12,1	12,7	13,3	14	14,7	15,4	16,1	16,9	17,6	18,3	19	19,8	20,5	21,2
MVT	Tis	166	170	187	191	198	205	213	220	227	236	244	252	259	266	274
Transfer PAX	%	19,8	20,7	21,7	22,7	23,7	24,7	25,7	26,7	27,7	28,2	28,7	29,2	29,7	30,2	30,7

At the beginning of 2006, a new Terminal 2 was opened which increased the capacity of service for another 10 years in one shot. On the other hand, the system of runways is not sufficient any more in the period of operational peaks, and without expansion it would become the main obstacle in the planned development of the Ruzyne airport. Prague airport plans opening and putting into operation a new parallel RWY in 2013-2015. Uncertainty with the term is caused by complications in the implementation of this project. The government of the Czech Republic approved the document "Czech Republic's Territorial Development Policy 2008" in July 2009 which also includes the parallel runway of Prague Ruzyne airport.

The company Letiště Praha (Prague Airport) was established in the frame of privatisation transformation from the state company Správa letiště Praha, s.p. (Prague Airport Administration, state enterprise) in February 2008. As of December 1^{st}, 2008 the company Letiště Praha, a.s. took over all rights and obligations of the previous state company, as well as its employees, business permissions, certifications, licences, and all processes and resources necessary for the functioning of the airport.

3.2 ORGANIZATIONAL ARRANGEMENT OF THE PROJECT TO BUILD A RAILWAY CONNECTION BETWEEN PRAGUE AIRPORT AND KLADNO

Cities and other entities interested in the construction of a modern railway connection between Prague – Prague Ruzyne airport – Kladno established the joint-stock company PRaK in 1993, the activity of which focuses on the implementation of the abovementioned project. Kladno is the largest town in the Central Bohemian region (about 75 thousand inhabitants) with a strong relation to Prague airport and Prague capital city, and also represents an important background base for universities. The whole project has been divided into two stages, namely the 1st stage (Prague, Prague Ruzyne airport) and the 2nd stage (railway station Prague Ruzyne – Kladno). Upon the grounds of documentation processed, especially in respect of traffic and construction solutions, there was a feasibility study of railway connection Prague – Ruzyne airport – Kladno processes in the frame of PHARE 9303-01-24 project in 1996. It was produced by the English engineering company Mott McDonald Limited in co-operation with Czech engineering companies. The study confirmed the uniqueness of the technical solution and provided direct, as well as indirect, economic, transport, and ecological merits of the project. Another advantage was that the study also determined the costs demands related to the project and defined the need for state subsidies, namely for reconstruction, doubling of rails and the electrification of the existing Prague-Kladno rail. Another important finding arising from the study was the clear argument that if the tariff principles of municipal and suburban traffic, as applied in Prague and the Central Bohemian region, were met it would be impossible, if no acceptable solution for investment incentive were provided by the state, to expect a direct payback of investment which could create an interest in the private sector to be involved in the project,. After the establishment of the new regional arrangement of the Czech Republic in 2000, the newly created Central Bohemian region started providing support to the abovementioned project, considering the section Prague - Kladno to be a pilot project for the Regional metropolitan rail system of public transport. This system is a part of the adopted Program of Regional Development as a part of the future system of traffic service in the region.

After many years of professional, as well as public, discussions, and many reports and studies processed in respect of the connection between the Prague airport and the centre of the city using underground or railway, the present situation may be characterized as follows:

- Both transport systems do not exclude each other in the Prague agglomeration, but complement each other due to the fact that the rail system shall also perform the role of a municipal railway in Prague.
- For the integration of air and rail transport, it is necessary to create a direct connection between the Prague Ruzyne airport and main railway station in Prague, where the long-distance trains stop (including the future high-speed lines). Discussions and preparatory work has already started in respect of a connection between "Masarykovo railway station" and the main railway stations in Prague.

The modernization of the railway Prague – Kladno with the branch line to Prague Ruzyne airport is embodied in the "Memorandum on Co-operation in Railway Traffic in the Area of Prague and the Central Bohemian region between the Ministry of Transport of the CR, Railway Infrastructure Administration (SZDC), Czech Railways, Capital City of Prague and the Central Bohemian Region" dated on July 2004. The Ministry of Transport and the Government of the CR consider the 1st stage of the project – the connection between Prague Ruzyne airport and the centre of Prague – as the most appropriate railway project for the implementation of the investment strategy known as "PPP" – public private partnership. The government resolution, dated January 19th, 2005, included the project "Modernization, operation and maintenance of the railway Prague, "Masarykovo railway station – railway station Prague Ruzyne and the construction of a new branch line, including its operation and maintenance, between Prague Ruzyne station and Ruzyne airport" in the first row of PPP projects under the code AirCon. Under the Act on the Transformation of Czech Railways, state organization (Act no. 77/2002 Sb.), Czech Railways ceased to exist on December 31st, 2002. By January 1st, 2003 two new successor companies were formed, namely Czech Railways and Czech Railways Cargo, joint-stock company and state enterprise Railway Infrastructure Administration (SZDC). This is why SZDC has become the investor of the project concerned (for the modernization of existing rails and construction of the new branch to Prague airport).

4 RISK ANALYSIS OF THE PRAGUE AIRPORT - RAILWAY NETWORK CONNECTION PROJECT

When looking for a solution to the project, all possibilities for the utilisation and modernization of existing rail tracks leading from Prague to the airport area and to Kladno town were considered. For the purpose of a clear comparison of all possible alternatives, the Ministry of Transport of the CR gave an order to the *Czech Technical University in Prague, Faculty of Transportation Sciences* to produce a comparative study of all the alternatives, including risk analysis, in 2007. The following Figure 1 shows the routes of all alternatives, which all require modernization and eventually construction of new missing tracks.

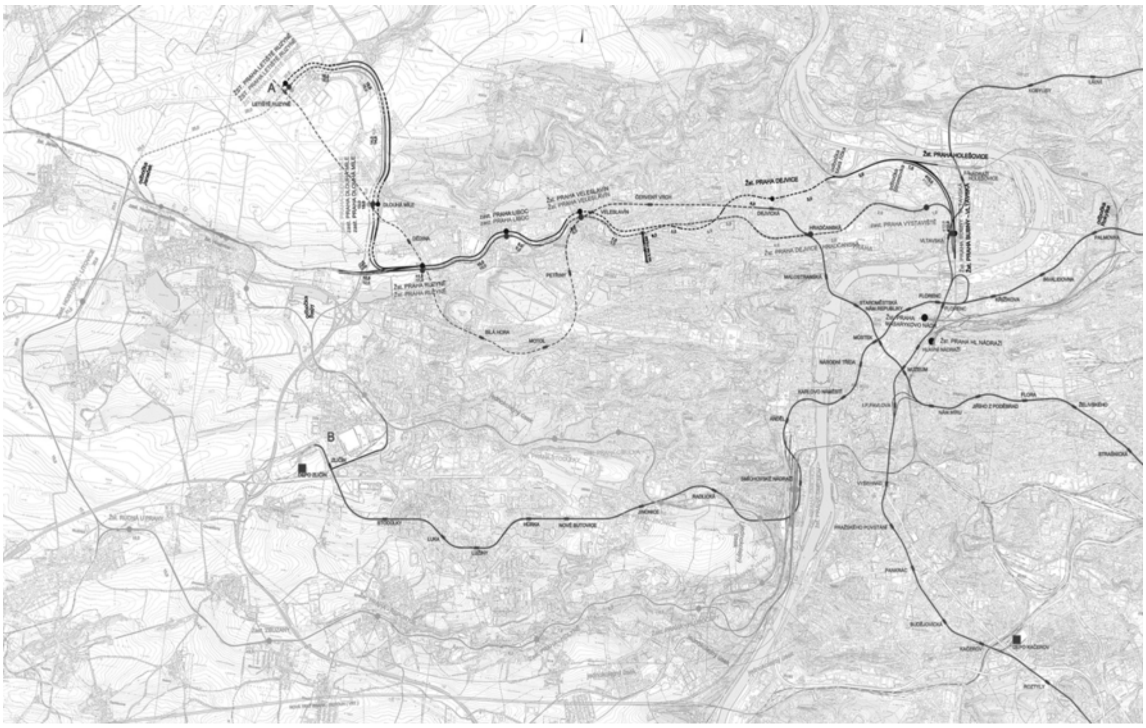


Figure 1: Map showing assessed alternatives for the connection between Prague city and Prague airport (Metroprojekt Praha, a.s.)

The subject matter of the risk analysis consisted of the options of the project for the railway link Prague – Prague Ruzyne Airport – Kladno, named according to the established names and designations of the railway tracks:

- **Option „Rudenska“ – R (green)**
- Leading in the existing corridor of track no. 173 (Prague Main Station) – Prague Smichov station – Rudna u Prahy and track no. 122 Rudna u Prahy – Hostivice, with a new construction of the branch Jenecek – Ruzyne airport;
- **Option „Semmering“ – S (violet)**
- Leading mainly in the existing corridor of track no. 122 (Prague Main Station) – Prague Smichov – Prague Zlicin – Hostivice – (Kladno), with a new construction in the area of Prague Zlicin (eventually branch Repy – Ruzyne airport);
- **Option „Bustehradska“ – B (red)**
- Leading mainly in the existing corridor of track no. 120 Prague Masarykovo railway station – Prague Bubny – Hostivice – Kladno, with a new construction of the branch Prague Ruzyne – Ruzyne airport;
- **Option „Holesovice“ – H (blue)**
- Leading in the track (Prague Main Station) – Prague Holesovice – branch Mala Ricka in the corridor of track no. 091, a new construction down to station Prague Veleslavin, and then following the option „Bustehradska“, i.e., track Prague Veleslavin – Prague Ruzyne in the corridor of the existing track no. 120, with a new construction of the branch Prague Ruzyne – Ruzyne airport.

The purpose of analysing the risks associated with these alternatives was to minimise the risk of failure of the alternatives – to identify the least risky version of the railway connection. The risk was understood as an event (generally called a risk factor), which can negatively influence the expected results of the examined alternatives of the connection.

The risk analysis was supposed to clarify:

- which risk factors are significant and most strongly influence the risk of the given alternative (or possibly which factors are insignificant and can be disregarded);
- how high the risk of the given alternative is and whether this risk is still acceptable or whether it is already beyond the limit of acceptability (risk assessment);
- what measures can be taken to reduce the risk of the given alternative down to an acceptable level (risk management).

Therefore, the analysis of the risks associated with the alternatives of the railway link was divided into the following stages:

- identifying the risk factors of the alternatives
- identifying the significance of the risk factors of individual alternatives
- identifying the risks of individual alternatives

4.1 IDENTIFYING THE RISK FACTORS OF THE ALTERNATIVES OF THE RAILWAY LINK

The basis for identifying risk factors consisted of the knowledge, experience and intuition of the employees who had participated in the preparation and implementation of the projects of a similar nature in the past. The actual identification of risk factors made it easier to structure the qualities of risk events (their contents) from the following points of view:

1. **The point of view of the infrastructure investor.**
2. **The point of view of the local administration as the regulator responsible for the development of the territory and the owners of complementary enterprises.**
3. **The point of view of the infrastructure users (citizens).**

Such an approach allows for a dialogue among all the involved entities; it is possible to analyse the differences in risk perception. The result of this stage is a written record of all the identified risk factors which can endanger the railway link project and which are structured according to the above-mentioned three points of view of the risk events' qualities [6]:

Risks on the part of an investor:

1. Risk on the part of a project leader
2. Risk on the part of construction
3. Risk of exceeding the investment costs
4. Risk of failure in the implementation of the project funding model
5. Risk of failure in keeping the project time schedule
6. Risk of failure in keeping project parameters
7. Risk of technical and engineering complications
8. Risk of permit procedures
9. Risk of appellate procedures
10. Environmental risks
11. Risks related to preservation of historical monuments
12. Risk of reduced revenues

Risks on the part of the local administration:

13. Risk of induced investments to city public traffic (MHD)
14. Risk of induced operational costs of MHD
15. Risk of increased expenditures related to the acquisition of real estates and land from private owners
16. Risk of not finishing the implementation of the territorial development plan
17. Risk of a wrong political decision
18. Risk of lack of co-ordination
19. Risk of other than expected impacts of the project

Risks on the part of infrastructure users (public):

20. Risk of longer travel time
21. Risk of increased vulnerability of the infrastructure
22. Risk of accident rate and transportation of dangerous materials

A high number of the identified risk factors could make further stages of risk analysis considerably more difficult. Yet, some of these factors can be entirely insignificant. This was why, subsequently, the significance of the risk factors was examined by experts, which made it possible to reduce the number of risk factors, which were then taken into account.

4.2 IDENTIFYING THE SIGNIFICANCE OF RISK FACTORS AND IDENTIFYING THE RISK OF THE EXAMINED ALTERNATIVES

The essence of the evaluation of the significance of risk factors by experts consist in this significance being examined by a group of experts from two points of view. The first point of view concerns the probability of occurrence of the risk factor. Thus, the threat that an undesired event will occur will be expressed as the probability of its occurrence (**O**). For quantification of the probability of occurrence of an event, the following scale was chosen [6]:

Degree	**The occurrence of the event is**
1	Improbable
2	Slightly probable
3	Averagely probable
4	Considerably probable
5	Almost certain

The second point of view is based on the intensity of the negative effect, the impact that the occurrence of the risk factor has on the success of the project alternative being examined. The impact (**I**) caused by an undesired event is expressed by its scope (extent) in which it affects the protected interests of the involved party. The following scale was chosen:

Degree	**The impact of the event is**
1	Negligible
2	Small
4	Medium
8	Large
16	Critical

With regard to the endangerment of the project's success, a risk factor (an undesired event) is the more significant, the more probable its occurrence is and the higher the intensity of the negative impact of this factor is. The risk factors that need to be regarded as significant are not only those risk factors whose probability of occurrence and, simultaneously, whose intensity of negative impact are high, but are also those risk factors whose probability of occurrence is very low but the intensity of their negative impacts is high. Therefore, for quantitatively assessing the significance of risk factors, it is not possible to choose the same linear scales for assessing both the probability and the intensity of a negative impact. If we used the scale of 1, 2, 3, 4 and 5 for the probability-related assessment, then it is necessary to use a non-linear scale, such as 1, 2, 4, 8 and 16, for assessing the intensity of a negative impact.

Fig. 2 shows the tabular representation of the significance of risk factors, seen from these two points of view. Both the probability of occurrence of the risk factors and the intensity of their negative impacts has five degrees in the above-mentioned chosen scales:

Based on an expert examination of the significance of risk factors, it is possible to arrive at a numerical rating of these significance levels, which is known as scoring. According to the results of the risk analysis (the probabilities and impacts of undesired events), risk assessment is carried out according to the chosen criterion values referred to as the "score" (**O x I**), which determines the gravity and acceptability of the risk. The variability of the score is also shown in the figure, based on the chosen scales. In the scoring process, the importance of the choice of a non-linear scale for rating the intensity of the negative impacts of the risk factors becomes even clearer. If a linear scale were used for the impact, such as 1, 2, 3, 4 and 5, then a factor with an almost certain occurrence and insignificant intensity of impact (5 x 1 = 5, that is, an insignificant factor) would be rated equally as a factor with a low probability of occurrence but with a critical intensity of its impact (1 x 5 = 5, which needs to be regarded as significant). If a risk is unacceptable, it is necessary to recommend carrying out a deeper risk analysis to identify the risks and subsequently to take measures to reduce the risks.

Risk assessed					
Negative effect assessment	Probability assessment				
	1	2	3	4	5
16	16	32	48	64	80
8	8	16	24	32	40
4	4	8	12	16	20
2	2	4	6	8	10
1	1	2	3	4	5

Figure 2: Tabular representation of the significance of risk factors

The values of the **O x I** criterion for identifying risk acceptability have been chosen as follows:

O x I	**Risk rating**
1 – 8	the risk is acceptable
10– 24	the risk is conditionally acceptable
32 – 80	the risk is unacceptable

The individual risks for each assessed alternative of the project, that is, **S, R, B** and **H,** can be sorted in this way according to their respective scores and it is thus possible to identify clearly the priorities with respect to further management of the project risks.In [6], we can find the identified tabular representations of the significance level of each risk factor.

It also contains a summarised overview of the results of the risk analysis in a graphical presentation in the form of bar charts for the purposes of further analyses and recommendations: the results of the risk analysis are shown for each of the alternatives **S,**

B, R and **H ,** where the individual risks are arranged in the order from the highest one to the lowest one, and the results of the comparison of the risks associated with the alternatives from the points of view of the investors, the local administration, and the transported public are shown. From the point of view of the three main parties involved, for example, three conclusions were drawn:

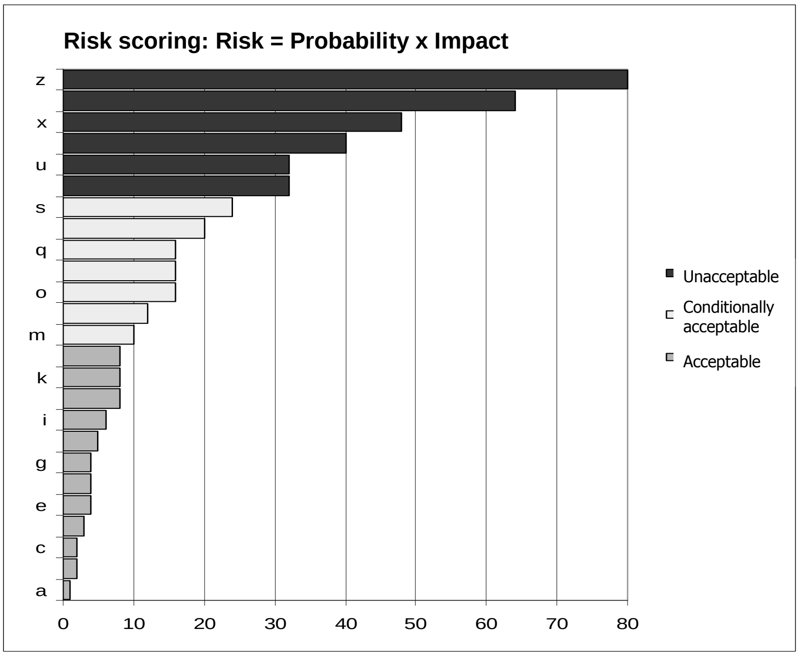
- **On the part of railway infrastructure investor:** classical three risks related to any large-scope project are dominating:
    - Maintaining the budget - *Risk of exceeding the investment costs, of failure in the implementation of the project funding model,*
    - Keeping the time schedule - *Risk of permit procedures, Risk of appellate procedures*
    - Maintaining the quality of the project - *Risk of technical and engineering complications.*

Last but not least *Environmental risk and risk of reduced revenues* turned to be important, too. The mentioned risks are effecting options **H, S and R** most negatively.

- **On the part of the local administration** *Risk of increased expenditures related to the acquisition of real estates and land from private owners, Risk of not finishing the implementation of the territorial development plan, Risk of lack of co-ordination, and Risk of other than expected impacts of the project* are dominating. These risks are again effecting options **H, S and R** most negatively. Also the *Risk of induced investment costs* is important and effects mostly option **B,** too.

- **On the part of public** *Risk of longer travel time* dominates in options **R** and **S.** *Risk of increased vulnerability and Risk of increased accident rate* dominates in options **R, S and H.**

The scoring results shown in Fig. 2 can also be represented graphically in a bar chart:



As the result of risk analysis there is a clear conclusion preferring the alternative **„BUSTEHRADSKA" – B.** This option satisfies the principle requirements of the task (estimated period of implementation, proposed capacity, etc.) and goes through a sunk tunnel of 6.2 km in length to the built-up zone of Prague 6 borough which would eliminate the effect of certain risks as perceived by the local administration. This option was then accepted by the municipalities concerned, as well as by the Ministry of Transport.

The connection of Prague Ruzyne airport to the future network of high-speed railway tracks (HST) belongs to a different category. Together with the proposal of a new railway tunnel connection meeting the parameters of HST between Prague and Beroun town, and continuing further to Pilsner town and Germany, the possibility to bring the high-speed tracks to the Prague airport is being solved. This could be realized through a branch starting at the level of Barrandov branch. The branch would then turn North-West and would lead in parallel to the arrival and departure runway RWY 13/31. The precise location of the station has not yet been determined. The track would then continue to the North and would be connected to HST leading to Dresden.

CONCLUSIONS

This article describes some principles and findings related to the harmonization of air and rail transport. Together with ground road connection, the hubs turn to inter-modal terminals for the transportation of passengers and goods. Such a defined inter-modal system shall probably be the solution for the present time, as well as for the future and may integrate the benefits of air and high-speed rail transport. The presentation also describes the history of long-term preparation of the railway connection to Prague Ruzyne airport and its assurance, including a risk analysis of such connection alternatives. Risk identification, assessment and management is a process, the goal of which is to optimise the risk. The first part of the process, which involves identifying, assessing and comparing the risks, provides the source materials necessary for the second part of the process, in which measures are taken to reduce the risks down to an acceptable level (effort to achieve an acceptable risk). While the first part of the process – risk identification and assessment – can be regarded as a purely scientific (multidisciplinary) activity, risk management also includes a political aspect, in addition to scientific disciplines (economics, sociology, psychology), due to the possible impacts of the taken measures.

The Prague project has been targeted as one of the pilot PPP financial strategy projects.

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Six-Year-Old Child Model in Frontal Sled Test

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ABSTRACT: This paper deals with a demonstration of a six-year-old child model. The model, called Bobby, belongs to a family of human rigid body models, Robby, and was created within the computational environment of the PAM system. First of all, Bobby is updated, the geometry and material properties of the original model are improved, and, in particular, joints, including their characteristics, are redefined. The updated model is tested in a sled test environment. Due to lack of experimental data with child cadavers, the test is compared to an experiment with the six-year-old Anthropomorphic Test Device, published in available literature sources.

KEY WORDS: biomechanics, virtual human model, six year old child, sled test, injury criteria.

1 INTRODUCTION

That the safety of child car passengers is still a current topic is demonstrated by the following facts. According to the European Child Safety Alliance, road traffic injuries are the leading cause of death and severe injuries among children aged 0–14 years, and are the cause of 34% of child injuries and deaths annually. New rules and standards concerning children's seats and restraint systems are continually updated. Most of the research uses dummy models (Malott et al. 2004; Palisson et al. 2007; Paine, 2001). However, human models are becoming more precise and more biofidelic (Haug et al. 2004; Číhalová, 2009) with the ability to understand human body behavior, and are able to describe injury analysis in more detail. The research community also tends towards the legalization of human body models in the car industry (Haug et al. 2003).

The paper deals with a six-year-old child model and its validation in a sled test environment. The model used, called Bobby, belongs to a Robby family of human articulated rigid body based models created within the long term cooperation with the ESI Group company (Haug et al. 2004). The Robby family furthermore includes a 50% male Robby and a 5% female Robina. A simple scaling tool for the creation of age dependent models was developed as well (Hynčík et. al. 2007). The original 50% male model Robby was successfully validated with experimental sled tests with human cadavers (Hynčík, 2001). Moreover, the Robby13, a scaled male body to that of a 13-year-old boy, was compared to the experiments carried out with the 13-year-old cadaver of a boy at the University of Heidelberg (Hynčík et al. 2007).

The aim of the study is to complete the Robby family with a tuned child model for impact purposes, and introduce a sled test. Since no experimental data of a six-year-old (6YO) boy are available, the Bobby sled test simulation is compared to the results presented in Malott et al. (2004) where the sled test with a six-year-old Anthropomorphic Test Device (ATD) is performed.

2 METHODS

2.1 Six-year-old child model

Bobby represents a six-year-old child who weighs 24 kg and is 1.13 m tall. The current model is based on the original version presented by Morille, (2001). From an anatomical point of view the model is represented by a skeleton covered by skin which serves for contact surfaces determination and also for the aesthetic aspect. From the mechanical point of view the body is created by 23 rigid bodies connected by 26 kinematic joints.

The rigid bodies represent particular body segments. The segment generally includes bearing bones and a particular part of skin. It is also characterized by its center of gravity (COG), mass and inertia properties taken from Morille, (2001).

Compared to the original version of Bobby, all joint elements and characteristics are defined according to Robbins, (1983) where the joint limits for an average adult male are published, since no similar child data are available. Except the spine, wrists and knees, all the joints in the body are of a spherical type. The wrist is compounded of two joints. The radius–hand joint is spherical and the ulna–hand joint enables translation in the vertical direction and rotation around the mediolateral axis. The knee joint of the spherical type is extended with one translational degree of freedom in the vertical direction. The spine is divided into four parts connected by flexion-torsion joints. The joints are between the first neck vertebrae (C1 called atlas) and the head (clivus), between the seventh neck vertebra (C7) and the first thoracic vertebra (T1), the third one is between the twelfth thoracic (T12) and first lumbar (L1) and last one connects the fifth lumbar (L5) and sacrum.

The remaining joints in the spine are of the flexion-torsion type. The shoulder girdle is created by two spherical joints between the clavicle and sternum and clavicle and scapula. Scapula slides over the rib-cage creating a so called physiological joint. The mutual joint orientation is given by local coordinate frames depicted in Figure 1, left. Penetrations during possible movement of particular body parts are prevented by sliding contacts.

2.2 Sled test environment

The simulation of a frontal sled test with a six-year-old child model is performed. The originally standing model is positioned into the sled. The sitting Bobby model can be found in Figure 1.

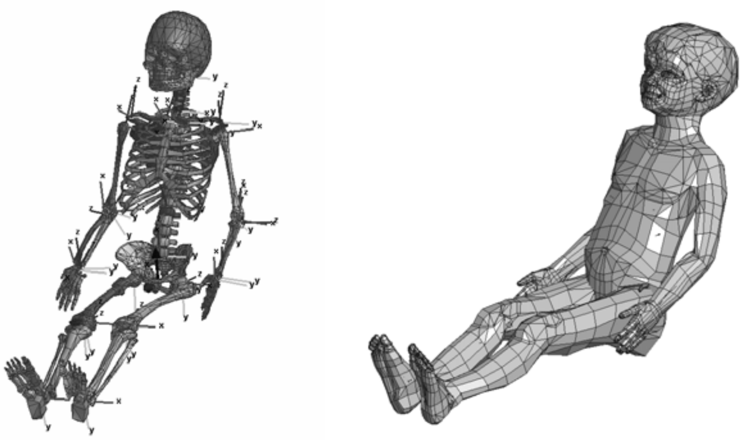

Figure 1: Bobby sitting in the car position.

The sled is carried out with a three point belt and a standard seat equipped with a child pillow (booster seat). The belt is without a force limiter and modeled as a fast belt system (PAM, 2006). The whole seat including the booster is modeled as rigid. The behavior of rigid bodies during the impact is refined by a soft contact involving stiffness of enclosed parts (PAM, 2006).

The arms, the feet and the back part of the head of the child model are preserved from penetrations with the seat by sliding interfaces. The generic 30 mph (corresponding to 48 km/h approximately) with 125ms duration American Automobile Manufacturers Association (AAMA) pulse is used, see Figure 2. The pulse acceleration is prescribed by the following expression:

$$a(t) = -168.73 \sin\left(\frac{\pi \cdot t}{0.125}\right). \qquad (1)$$

The child model is accommodated by accelerometers giving the local accelerations in the head, spine and pelvis.

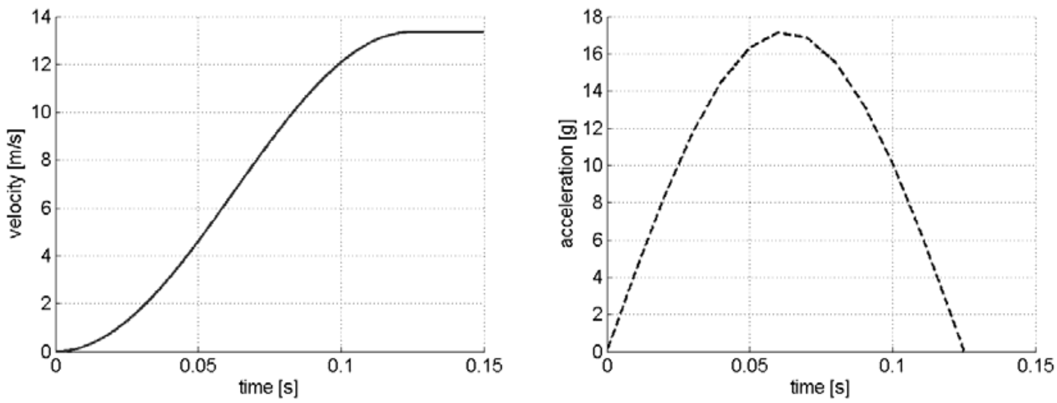

Figure 2: Time-velocity and time-acceleration dependencies of AAMA sled pulse.

2.3 Injury criteria

The severity of an injury is described through the so called injury scales. The most widely used injury scale is the Abbreviated Injury Scale (AIS) which was first developed in 1971 and it is still being updated; see Eppinger et al. (1999). Using rigid body models we are not able to directly recognize accident consequences on a human body. The measure of injury is determined by different injury criteria based on body parts acceleration or on tension force and bending moment which are summarized in Schmitt, (2004).

Table 1: Summary of injury measures.

Injury measure	IARV
Neck - N_{ij}	1
Chest - 3ms	60
Head – HIC_{15}	723

The standard HIC_{15} criterion is used to treat the head injury, the N_{ij} criterion for the neck and finally the 3ms criterion for the thorax is applied. The particular Injury Assessment Reference Values (IARVs) for six-year-old ATD are summarized in Table 1. The used IARVs represent a 25% chance of an AIS ≥ 3 injury, and they are specified by NHTSA in Eppinger et al. (1999) except the HIC_{15} which is taken from Mertz et al. (1997). Table 2 states the critical intercept values limiting the “safety” area (marked by the solid line in Figure 7) used for N_{ij} determination.

Table 2: Limits for neck injury criteria for the 6 year old dummy (PAM, 2006)**.**

Load	Critical intercept values
Tension [N]	2800
Compression [N]	2800
Flexion [Nm]	93
Extension [Nm]	37

3 RESULTS AND DISCUSSION

Since no experimental data for a six-year-old (6YO) boy are available, the Bobby sled test simulation is compared to results presented by Malott et al. (2004) where the frontal sled test with a six years old ATD is performed.

3.1 Sled test kinematics

The overview on the body behavior of the 6YO child model during the sled test can be described as follows. During the first 60 ms the body moves forward due to inertia forces. Then the body is restrained by the belt system, and the flexion of its upper part occurs. After 140 ms the body starts to move back. The upper and lower extremities are pushed up. The kinematics are documented in Figure 3 at different times. The comparison with the 6YO ATD with the backless booster variant (Malott et al. 2004) is shown in Figure 4.

The model’s kinematics are monitored and accelerations are measured in the head and in the first thorax vertebra and in the sacrum of the child model. These dependencies are used to compute injury measures analyzed in the following paragraph. They are shown in Figure 5. The curves are filtered by Sae180 filter to emphasize important peaks. All the curves follow a similar trend.

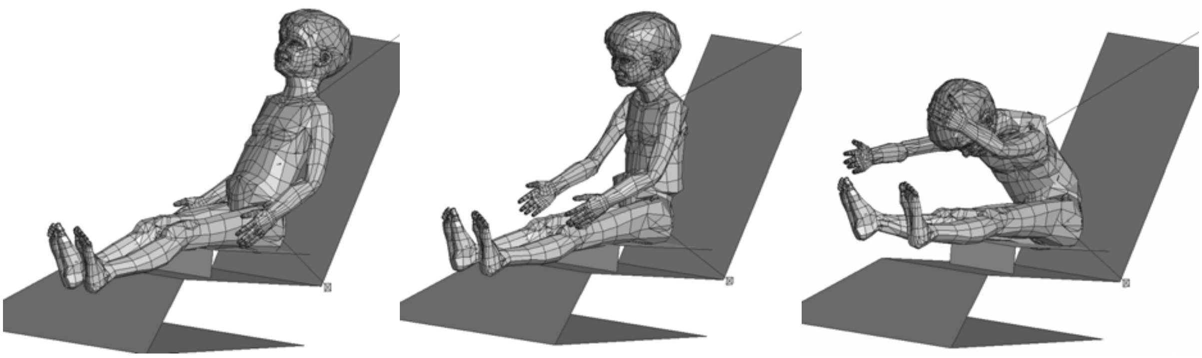

Figure 3: Sled test kinematics at 40, 80 and 120 ms.

The experimental belt peak forces occur between 2000 N and 3500 N in the case of the lap belt and between 2000 N and 7500 N in the case of the shoulder belt for various experimental settings. The back less booster variant which corresponds to the presented simulation is assessed in Table 3.

Since detailed belt characteristics are not specified in Mallot et.al. (2004), the standard fast belt system is used. The belt system generates the greatest force between 60 and 130 ms. The lap belt peak force corresponds to the experimental one, while the shoulder experimental one is greater as summarized in Table 3.

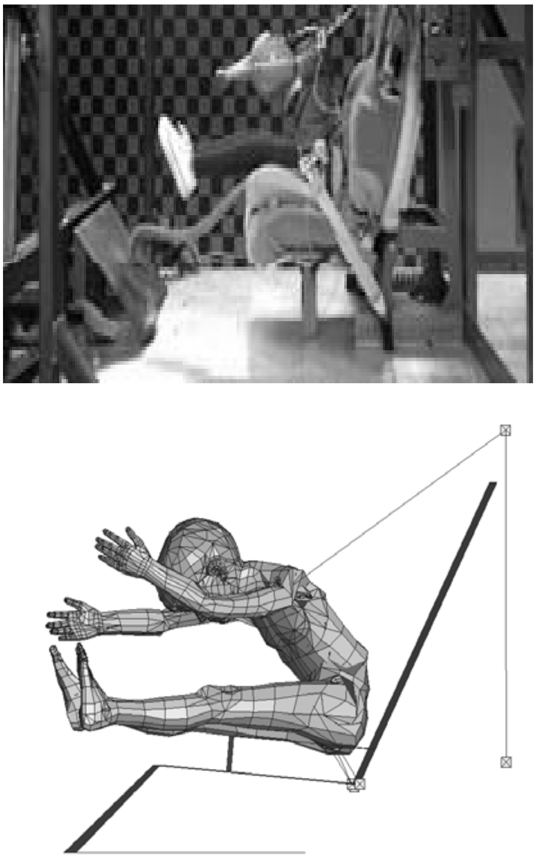

Figure 4: Experimental ATD's (Malott et al. (2004)) and Bobby's kinematics at 120 ms**.**

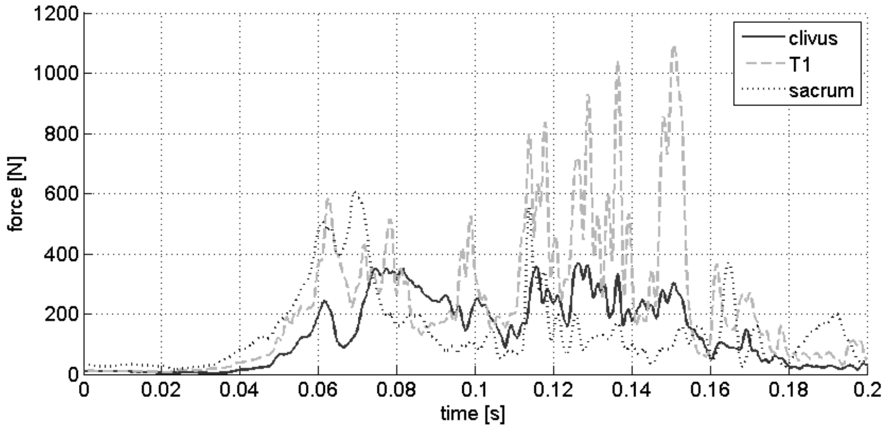

Figure 5: Acceleration magnitude of the head (Clivus), the first thorax vertebra (T1) and the sacrum.

3.2 Injury analysis

The results are computed from filtered acceleration curves, where the filters are chosen according to recommendations published in PAM, (2006).

The graph in Figure 7 shows the neck tension (measured in the first cervical vertebra). It would be critical if the points exceed the marked region. The kite shape determines the injury limit corridor for the 6YO child, see Schmitt (2004). The flexion moment at the horizontal axis goes from extension (negative part) to flexion (positive part), and the vertical axis expresses the axial force from compression (negative part) to tension (positive part). Circles note the forces in the C1-head joint in time.

During the first 60 ms the head is subjected to compression with soft flexion and then soft extension. Between 60 and 110 ms the tension and soft flexion occurs, between 110 and 140 ms tension and extension, and after 140 ms the circles oscillates around the origin. The greatest loading can be observed when the greatest belt force is generated.

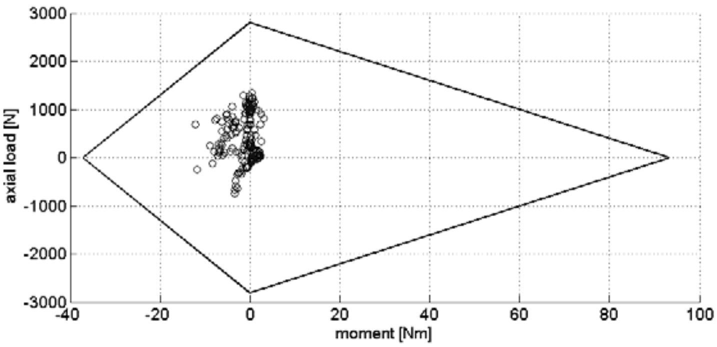

Figure 7: Axial load and bending moment dependency measured in the occipital condyle during the sled test.

The Bobby's injury analysis is compared to experimental results obtained with 6YO ATD. The simulation results are slightly lower than the experiment's, as can be seen in Table 3. The injury measures are normalized by the particular IARV. Concerning HIC_{15} and 3ms, both the values are well under the injury limit so the differences are not crucial in this case.

Table 3: Comparison of 6YO ATD's and Bobby's characteristics.

	6YO ATD	Bobby
Shoulder belt peak force [N]	7100	2800
Lap belt peak force [N]	2100	2400
Chest acceleration (3ms) normalized by IARV	0.61	0.57
HIC_{15} normalized by IARV	0.28	0.12
N_{ij}	0.98	0.79

4 CONCLUSION

The demonstration with a rigid body based model of a six-year-old boy was presented. The model completes the Robby family of articulated human models designed for crash test purposes. Firstly, the model was updated; principally, the rigid bodies and joints structures and joint characteristics were corrected.

Bobby's behavior in the frontal sled test was successfully compared to experimental results performed with the 6YO ATD. The results were analyzed by virtue of injury criteria. The standard head (HIC_{15}), neck (N_{ij}) and thorax (3ms) criteria were applied.

ACKNOWLEDGEMENT

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Detection of Steel Bars in Concrete by Impact-Echo

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ABSTRACT: Due to the impact-echo defectoscopy tests of a massive block of under-reinforced concrete steel bars of diameter 22 and 32 mm were detected. This fact is described in the paragraph, and results are provided through a visualization of b-scanning. The effect of a concrete cover layer and of the reinforcement diameter is clear on the sensitivity of the method. Because of various parameters of the reinforcement, impactors of a different ball diameter were employed. With a ball of diameter 12 mm, 8 mm and 5 mm reinforcement at the depth of about 50 to 60 mm was detected.

KEY WORDS: Impact-echo, concrete, non-destructive testing of steel bar detection.

1 INTRODUCTION

Concrete structure condition can be deduced from destructive and non-destructive testing (NDT). There is no standard definition for nondestructive testing (Carino, 1999). In general, tests that do not alter the concrete are considered as NDT methods. NDT methods can be used to detect various types of defects like voids, honeycombing, delaminations, cracks, lack of sub-base support, etc. Some instrumental methods are helpful in integrity evaluation:

- stress wave propagation methods (acoustic methods, IE, ultrasonic methods)
- infrared thermography
- ground penetrating radar (GPR), called also radar

The techniques for flaw detection are generally based on the following simple principle: the presence of an internal anomaly interferes with the propagation of certain type of waves. The presence of the anomaly can be inferred by monitoring the response of the test object when it is subjected to these waves. Impact-Echo Method (I-E) is treated as the one of the most promising NDT techniques for the assessment of concrete structures.

2 PRINCIPLE OF IMPACT-ECHO METHOD

Impact-echo is a method for the non-destructive evaluation of concrete, based on the use of an elastic, low energy impact on the surface generating low frequency stress waves (mainly below 60 kHz). These waves consist of compression (P), shear (S) and surface Rayleigh (R) components which propagate through the structure and are reflected by interfaces within the material or external boundaries. I-E method is very often used for the quality assessment of concrete structures in the following purposes:

- estimation of member thickness from one side
- detection of internal flaws such as voids, delaminations, honeycombing
- estimation of the depth of surface-opening cracks
- evaluation of multilayer system quality

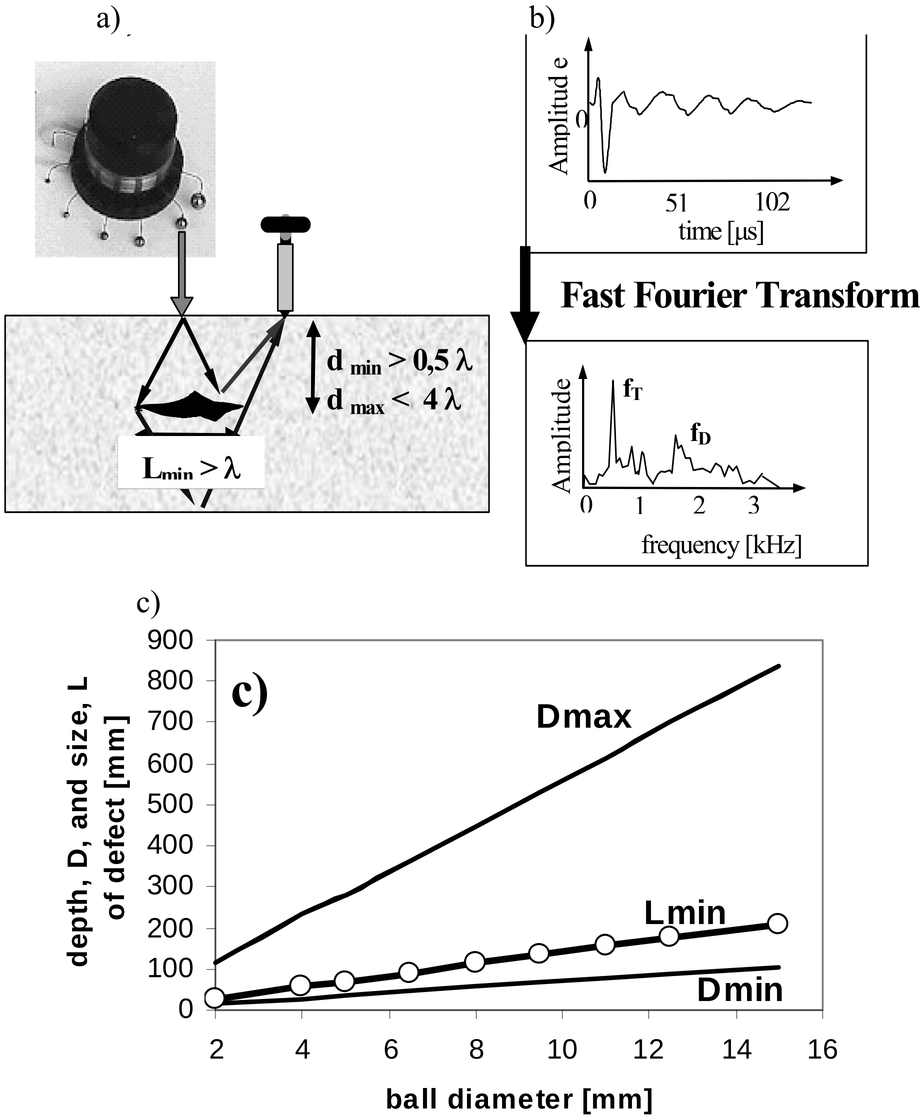

Figure 1: Scheme of impact-echo method a), examples of waveform and corresponding frequency spectrum; b) and c) effect of ball size on depth and size of defect possible to detect

As the stress waves generated in the I-E method (Fig.1a) have low frequencies (in comparison to, for example, ultrasonic waves) this method is less sensitive to natural heterogeneity of concrete. An additional feature of the I-E method is an application of frequency analysis besides a time-domain analysis (Fig 1b). The selection of the impact source is an important factor for defect detection. The impact duration determines the frequency content of the stress wave and determines the minimum flaw depth that can be detected (Fig.1c). Please note that according to Fig. 3b it is possible to detect a steel bar of even half the minimal dimension (diameter) L_{min} and cover D_{min} in comparison to the defect as delamination or void mentioned in Fig 3c.

On the basis of the frequency spectrum the depth of the reflecting steel interface can be determined according to the relationship (1),

$$\mathbf{D = \beta\, C_p / 4\, f} \qquad (1)$$

where: D - depth of interface, C_p – P-wave velocity, f – frequency of dominant peak in frequency spectrum, β is a “shape factor” that depends on the geometry of the structure being tested, and the key frequency —called the “thickness frequency” — is the vibration frequency induced by multiple P-wave reflections between the top and bottom surfaces. The shape factor $\beta = 0.96$ is valid for a plate structure.

In figure 2 there is scheme of stress wave propagation. In figure 3 the frequency spectra by testing of steel reinforced concrete is shown.

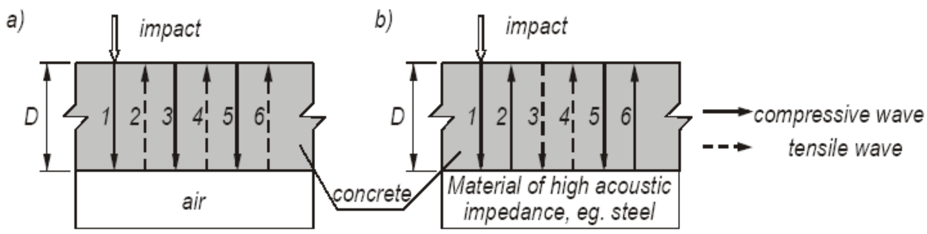

Figure 2: Scheme of stress wave propagation: a) concrete/air and b) concrete/ steel – material with higher stiffness (Sansalone & Street, 1997)

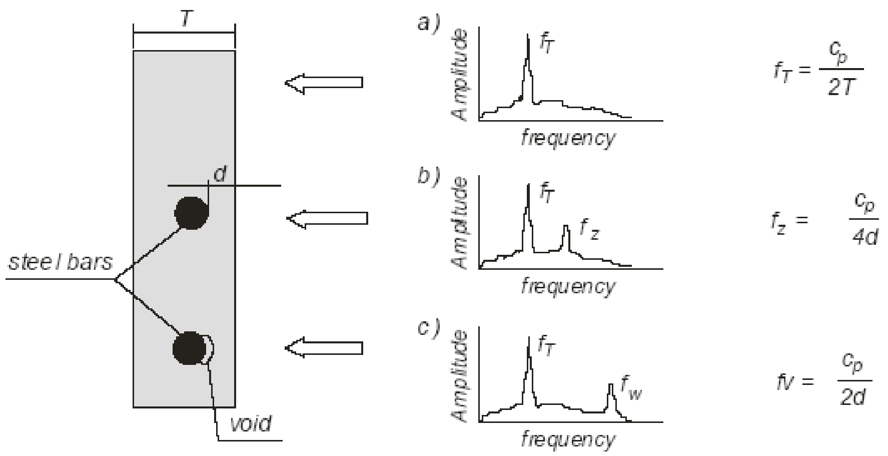

Figure 3: Scheme of steel bar localization with impact-echo method: a) place without reinforcement b) place with reinforcement, c) air void at the interface bar/concrete (Runkiewicz, 2002)

3 SPECIFICATION OF TESTED AREA

The tested concrete block is located in the yard of the Civil Engineering Faculty of Brno University of Technology, it has a complex shape (Fig.4a) – from the point of view of impact-echo testing – a plate structure is preferable in this method. The layout dimensions are 1.8 x 1.8 m, the height of the block is 1.5 m. Measurements were done in the front wall of the block (Fig.4b) where all the implemented defects were located, in the points of previous ultrasonic testing. The point symbols of the ultrasonic grid, 10 x 10 cm, were used in the I-E analysis. Nevertheless the grid of I-E testing points was 10 x 20 cm – more frequent in horizontal direction. The tests were performed with DOCter impact-echo system produced by German Instruments.

a) b)

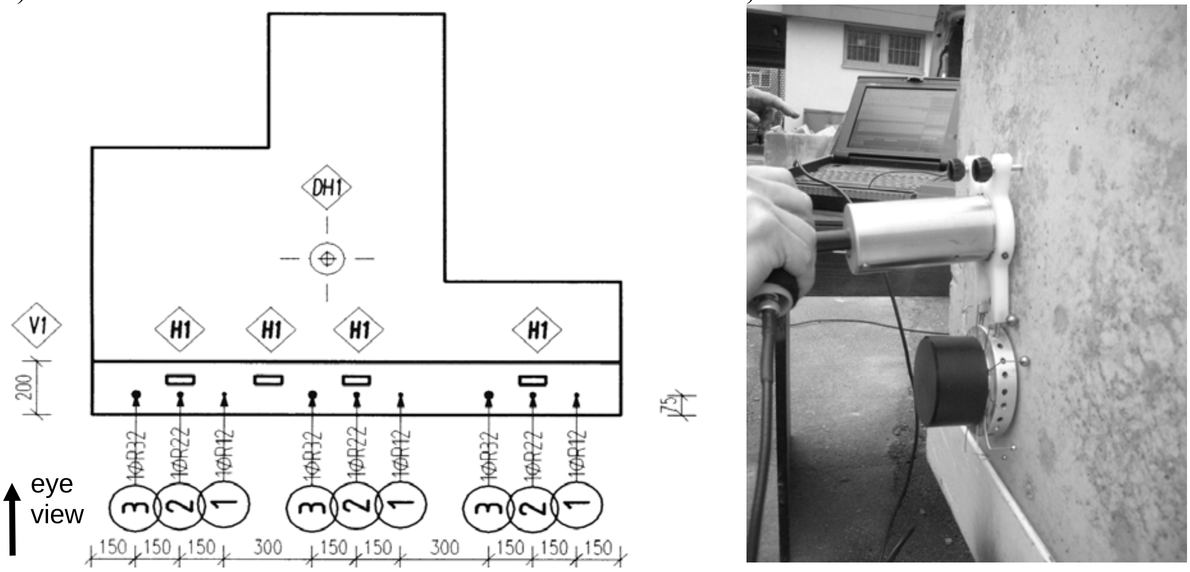

Figure 4: Schematic layout of the concrete block with artificial defects a) side view of the front wall measuring by DOCter I-E system b)

4 CONDITIONS OF THE TESTS

The irregular shape of the block causes multiple reflections of stress waves and a high effect of the surface wave (R-waves) on a signal and a frequency spectrum. The signals contain a high amplitude normal R-wave or a repeatable, abnormal, separated R-wave. Therefore, it was necessary to cut R-waves in every signal for further analysis. Additionally, the irregular and non-plate shape of concrete member caused multiple reflections of the P-wave. As a result, besides the fundamental mode, the additional modes of vibration are visible in the frequency spectrum. The particular modes usually are calculated on the basis of eigenvalue analysis. In the case of the tested blocks the D/B ratio (D – thickness of the member in impact direction, B – shorter cross-sectional dimension) is higher than 0.8. According to the impact-echo principle if the d/B ratio is higher than 0.9 the fundamental mode has a large amplitude and one higher than the amplitude of the next modes of vibration.

In further tests frequency distribution is characterized by the distribution of a relative frequency that can be understood as a point in the frequency domain. The frequency interval (interval between subsequent points in the frequency domain) equals 0.488 kHz at the sampling period of 2 μs used in the tests.

Frequency spectra for concrete blocks is similar and characterized by a sharp peak of a fundamental mode of vibration, f_1, (relative frequency = 7) and successive modes: $1.71f_1$, $2.141f_1$, $2.71f_1$ and $4.00f_1$ (relative frequencies: 12, 15, 19, 28). In the case of the front wall of the block the fundamental frequency peak is wider and mode 2 is less visible; additionally, mode $3.00f_1$ (relative frequency: 21) appears in the frequency spectrum.

The spectra obtained for the concrete block were used to determine the shape factor. The thickness frequency could be equal to 6 or 7, due to the digital recording. The shape factor was calculated taking into account the signal in the centre of the front wall and the P-wave velocity measured with an ultrasonic method (4000 m/s). The shape factors for point 6 and 7 were equal to 1.02 and 0.87 respectively. The average value of the shape factor equals 0.95, which is close to the 0.96 typical for plate-like structures. The shape factor 0.96 was taken for further analysis.

4.1 Detection of the steel bars

If defects or reinforcement are present in the structure the amplitudes of particular *modes* should be lower, while the amplitude of frequency peak corresponding to the reflection from the defect is higher. The spectra determined for the very base of the block should be carefully examined because of a possible reflection from the steel support. The considerations above indicate that, for further analysis of frequency spectra, *it is necessary to calculate expected frequencies* corresponding to a reflection from particular types of artificial defects in a tested concrete block. In this case there are:

- steel bars
- defects of honeycombing types
- plastic ducts filled with cement mortar

According to the impact-echo principle, steel bars can be detected if the ratio of bar diameter to its depth is higher than 0.3. In this case only steel bars of ∅32 and ∅22 fulfill this requirement, and they should be visible at the relative frequency 33-35 and 25 – 27, respectively. Steel bars ∅12 cannot be significantly detected in this situation. In table 1 the expected frequencies are shown calculated on the basis of this relationship (1).

Table 1: Expected peaks in the (relative) frequency *f* spectrum corresponding to the reflection from steel bars, according to the distance measured on the top of the block

Bars diameter		∅32	∅22	∅12
Horizontal position in the grid		N, H	O-P, I-J	Q, K
Distance from surface D [mm]		50	55	60
P wave velocity [m/s]	3800	(33) 16 kHz	(25) 12 kHz	(21) 10 kHz
	4000	(35) 17 kHz	(27) 13 kHz	(23) 11 kHz

5 RESULTS OF I-E TESTS

Taking into account the approximate layout of the artificial defects and armature (Fig 4a), and knowing the expected relative frequencies (Table 1), the correct answer of the stress wave propagation can be obtained.

In figure 5 are the results of impact-echo tests carried out in the front wall of the concrete block by an impact ball of various diameters. The layout of the reinforcement in the structure can be derived transforming (relative) frequency *f* of the highest amplitude by equation (1) onto the depth D.

a) b) c)

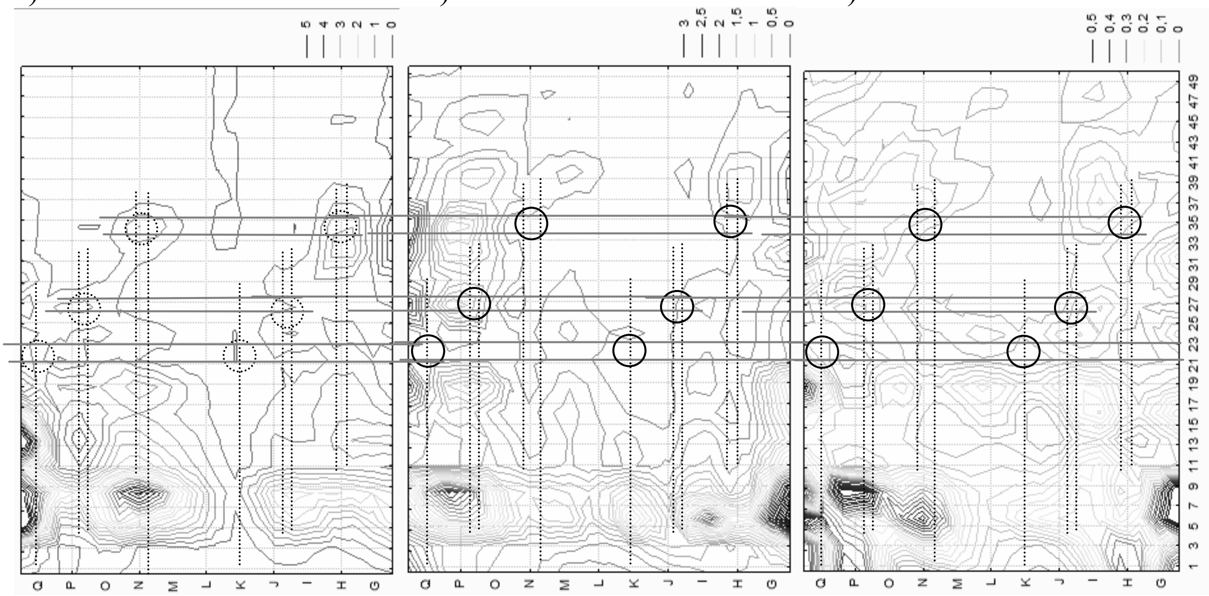

Figure 5: Relative frequency spectra (a-scan) samples composed into horizontal b-scan of the front wall of the concrete block tested by ball impactor of diameter 12 mm a), 8 mm b) and 5 mm c).

6 CONCLUSIONS

With a 12 mm impact ball a steel bar ∅32 was detected exactly in the expected positions (50 mm cover) according to the velocity of P-wave (3900 m/s) determined by the ultrasonic instrument before the I-E test. Reinforcement ∅22 mm was rather noticeable by balls of a smaller diameter (8 mm) at a depth of about 55 mm. Bars ∅12 mm were only roughly detectable in the case of 5 mm ball testing, a better estimation of their position was produced by a 12 or 8 mm impactor. In conclusion, using a 12, 8 or 5 mm ball it was possible to find all steel bars inserted into the massive concrete block. The approximate position of armature/defects (honeycombing, flaws, etc.), and P-wave velocity (quality of concrete) is necessary to be known before testing by the impact-echo method.

ACKNOWLEDGEMENT

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Pedestrian Detection

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ABSTRACT: Driving maneuvers are described that may reduce collision consequences or that can prevent collision, in this case, with the vulnerable road user – the pedestrian. For such a level of collision prevention, some intelligent system is needed. A simple, built-in near infra red night-vision system for vehicles is described, along with results of the tests focusing on increasing the visibility of a pedestrian.

KEY WORDS: collision avoidance, object tracking, object detection, field of view, visibility.

1 INTRODUCTION

Passive safety, which is nowadays realized and applied to personal vehicle construction, undoubtedly has its advantages and helps to protect vulnerable road users when they are hit by the vehicle. From the point of view of pedestrian protection it seems to be advantageous to effectively use all the available time before an unavoidable accident. Between the detection of danger and the time of collision a certain amount of time always elapses. This very short time interval contains lot of possibilities which can be investigated.

2 COLLISION PREVENTION

It is theoretically and practically possible to prevent a collision in two ways. The first is to brake – decelerate or stop. The second method is to steer away from the collision point. Each of the maneuvers has its own potential within certain varying intervals of speeds. Braking is better at lower speeds. This is good to use in the city. Steering out of the way is better at higher speeds.

The reason for this is the limited possibility of quick speed reduction at higher speeds. The best effect most decidedly will bring synchronous braking and steering, i.e., the combination of both maneuvers at one moment. The very last moment of collision avoidance depends more or less on the position of the obstacle. As the TTC is constant, the avoidance maneuver must start earlier (if speed is higher), which means at a longer distance (see Figure 1).

The system of emergency braking may be activated in the last phase, which means at the moment at which the collision is already unavoidable. At this moment there is no chance to absorb all the kinetic energy with brakes. We are not able to completely avoid the collision. But if we pre-adjust the brake system and if we help the driver to maximize the brake pressure from the first moment of the brake pedal depression, we can reduce the impact speed. This is one of the steps that reduce MAIS2+ injuries in the agglomeration area.

To automatically control the brakes some detection system is needed.

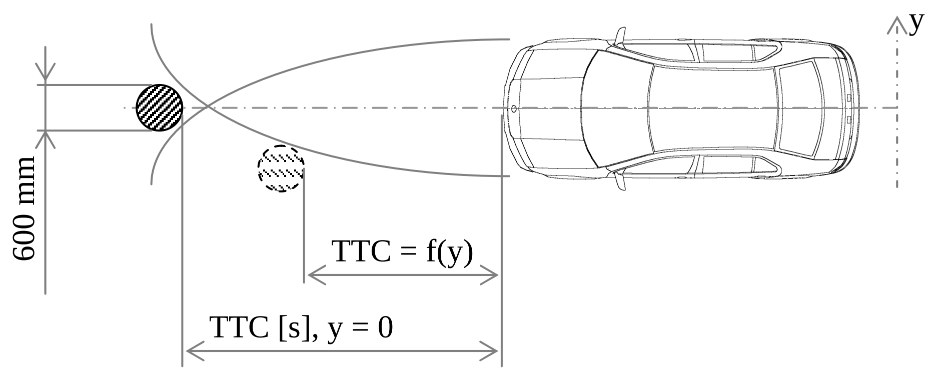

Figure 1: definition of the last moment for the beginning of steering maneuver

3 OBJECT TRACKING

Generally tracking can be done for the following two purposes:

- in the early stage, for driver information (like night vision systems with pedestrian recognition);
- in the pre-crash stage (TTC ~ 2sec.) for the driver's final warning and pre-adjustment of active and passive components and systems.

Front view camera systems have big potential. They can be used for safety and for comfort functions at the same time. This brings with it a good synergy that is welcomed by the customer. The camera may not only be used for day time pedestrian detection, but also for night vision with pedestrian detection and for driver assistant systems, such as, for example, lane keeping support, high beam control and real-time traffic sign recognition.

NIR	FIR
camera	camera
electronic control unit	electronic control unit
NIR source of light	x
monitor/HUD	monitor/HUD
up to 180 m	up to 300 m
800 – 2500 nm	50000 – 500000 nm

Table 1: comparison of Far and Near Infra Red system

For the Near Infra Red (NIR) systems we need to integrate the NIR camera with the electronic control unit into the car. The vehicle has to be equipped with an NIR source of light. This source can either be a normal halogen bulb with a build-in special filter, an Infra Red (IR) laser or a special IR LED. These systems usually influence the construction of front lights. The advantage of NIR NV is that the shown picture on the monitor or on the Head-Up Display (HUD) is more real than a black and white picture.

For the Far Infra Red (FIR) system we need to integrate the FIR camera with a control unit. The camera chip is sensitive to the heat that is emitted by the objects in the field of the camera view. The more heat that is emitted by the object, the lighter the pixel displayed on the monitor. The orientation on the display is worse in comparison to the NIR system, but it may have more advantages if we want to build in an automatic pedestrian detection system.

Both these technologies are mature, suitable and available for personal vehicles, and light and heavy trucks.

4 TEST RESULTS

For the purpose of the pedestrian test, a test vehicle was rebuilt. The front lamps were equipped with the near infra red source of light. The automatic mode always switches on these lamps when the vehicle speed exceeded 30km/h, which is suitable for the daily function of the system.

For the test, it was possible to switch the automatic mode to a manual mode. It is then also possible to make static tests on the test track. Two solutions were considered for displaying the picture, either a simple monitor or a head up display. The head up display was chosen due to the better estimation of driving tests in real traffic.

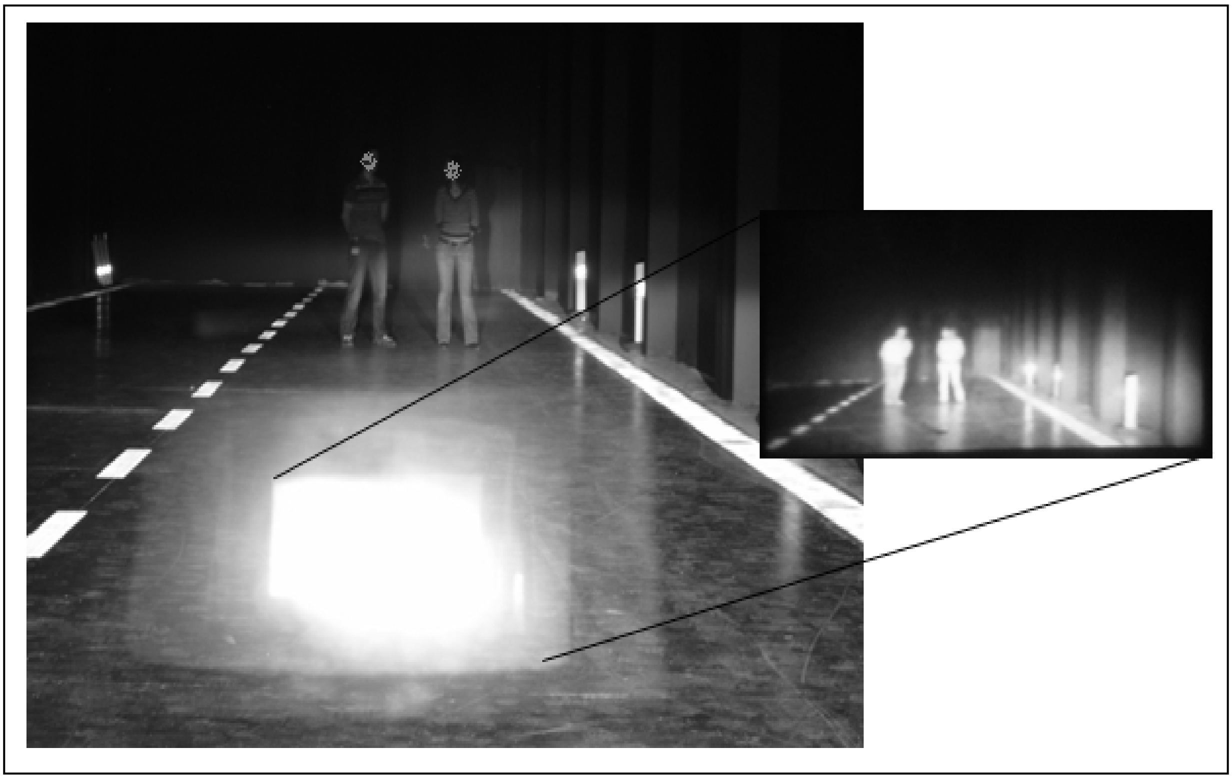

Figure 2: Pedestrians at a distance of 25 m

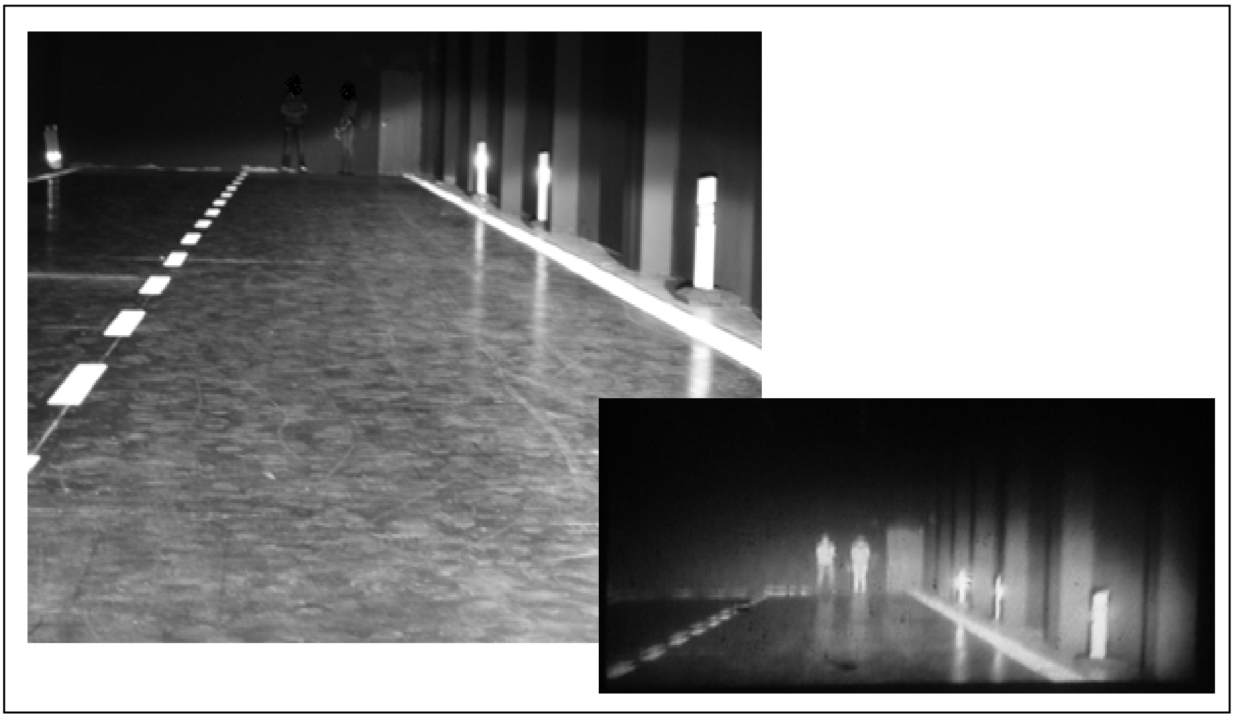

Figure 3: Pedestrians at distance of 50 m

5 CRASH DYNAMICS

The crash dynamics depend on the initial conditions, especially on the impact speed, which can be dramatically reduced by utilizing the methods described in the previous text.

The collision dynamics can be tested by using the real crash tests or by mathematical simulation, mainly based on the commercial software packages (MADYMO, SIMPACK, PAM-CRASH, LS-DYNA, RADIOSS, ABAQUS). The validation tests are basic tools for finding the unknown parameters (material damping, etc).

The MAYMO and SIMPACK software packages are based on multibody dynamics descriptions (the second order differential equations of motion are derived automatically), the PAM-CRASH, LS-DYNA, RADIOSS, ABAQUS are based on the finite elements methods (FEM). The multibody approach (MBS – multibody systems) enables relatively fast calculations and therefore the optimization of the dynamics by repeated simulations.

Figure 4: Records from the high-speed camera

The FEM results offer the stress and strain analysis to the user. The aforementioned MBS software packages offer the interfaces to the other methods, for example, some parts of the dynamic system can be deformable and simulated by the FEM approach.

The MADYMO has a rich database of crash test dummies and biomechanical injury criteria. The SIMPACK is strong mainly in active safety, enabling us to simulate active vehicle feedback systems by connecting with MATLAB/SIMULINK.

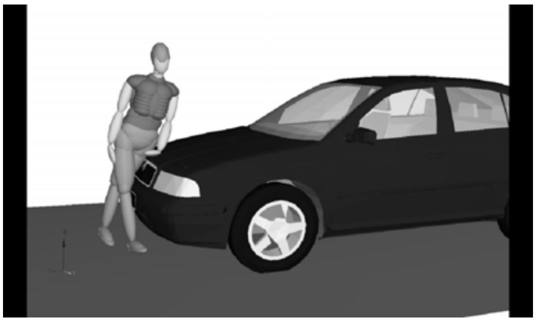

Figure 5: Animation from a MADYMO simulation

6 CONCLUSION

Real driving situations show that the advantages of pedestrian monitoring systems increase extremely with the implementation of a detection algorithm. This is difficult, state of the art work. But successful pedestrian detection brings with it even more advantages.

First of all, the driver does not have to watch the display instantly. The detected pedestrian can be highlighted as shown in figure 6 only when there is the danger of a collision. In such a case an acoustic warning may sound. Or even better, the braking system can initiate the deceleration of the car. Some vehicles support the driver with steering recommendations as soon as the car starts to skid. It is possible such a steering recommendation would also be helpful in preventing a collision with a vulnerable road user, i.e., the pedestrian.

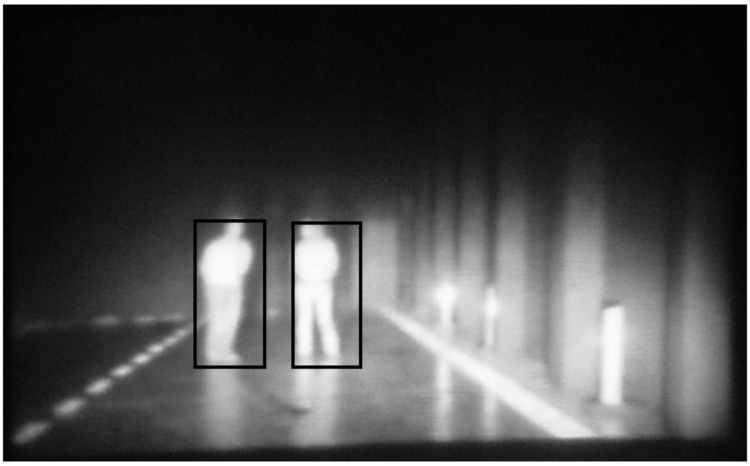

Figure 6: graphic example of the highlighted pedestrian on the on-board screen

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Study of the Temperature and Acoustic Emission Characteristics of the Concrete Hardening Process with Different Ways of Curing

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ABSTRACT: Concrete is a basic building material. This article describes its properties. Microcracks result from volume changes in concrete. The intensity of temperature development and the way concrete is being cured have a significant influence on the emergence of microcracks. Indeed, the quantification of microcracks isn't simple. Using acoustic emissions it is possible to observe the evolution of scratches in hardening concrete – how many of them evolve and how the intensity of their emergence changes depending on different regimes of curing or different types of concrete (different cement batches, various additives and admixtures, etc.).

KEY WORDS: Acoustic Emission Method, concrete, hardening, microcrack, Non Destructive Testing, High Performance Concrete

1. INTRODUCTION

High Performance Concrete (HPC) can be defined as a concrete made with appropriate materials (super-plasticizer, retarder, fly ash, blast furnace slag and silica fume) combined according to a selected mix design and properly mixed, transported, placed, consolidated, and cured to provide excellent performance in some specific areas of the properties of concrete, such as high compressive strength and high durability (high density, low permeability, and good resistance to certain forms of attack). An important part of concrete quality is concrete setting. However, there are some new problems. (Bilek et. all., 2001; Morin R. et all,2002)

The hydration of cement is an exothermic process. During hydration concrete obtains strength and other mechanical properties but it also shrinks. While for usual concrete drying shrinkage is the main component of total shrinkage, in the case of HPC the role of autogenous shrinkage increases. The shrinkage affects the creation of micro-cracks which lower the durability of the concrete. The course of total volume exchange is affected by temperature development, see Figure 1.

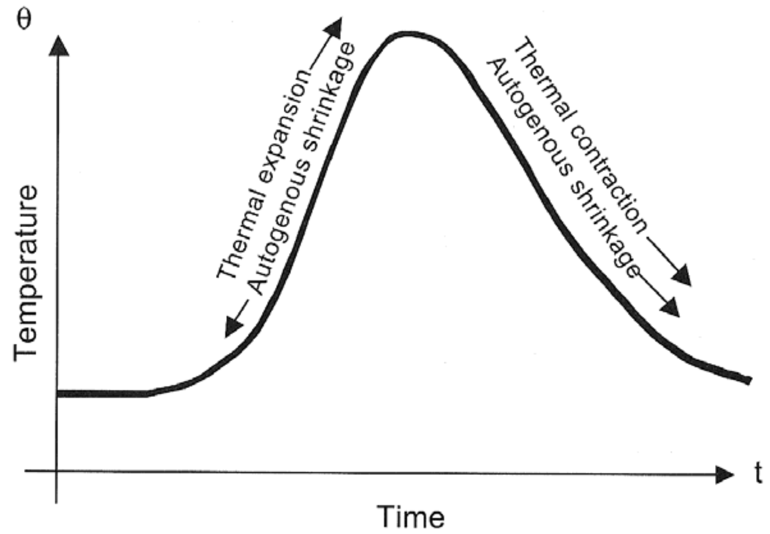

Figure 1: Why is important to know the heat development course of concrete. (Aitcin, 1998)

On the basis of the temperature course it is possible to select the best way of concrete curing to avoid micro-cracking. During the early stages of curing the autogenously shrinkage decreases thermal expansion. After the peak temperature is reached, however, autogenously shrinkage and thermal contraction act together in reducing volume and thereby creating micro-cracks. (Aitcin, 1998)

Acoustic Emission is the class of phenomena whereby an elastic wave, in the range of ultrasound (usually between 20 KHz and 1 MHz), is generated by the rapid release of energy from the source within a material. The elastic wave propagates through the solid to the surface, where it can be recorded by one or more sensors (see Figure 2). The sensor is a transducer that converts the mechanical waves into an electrical signal. (Pollock A.A., 1988)

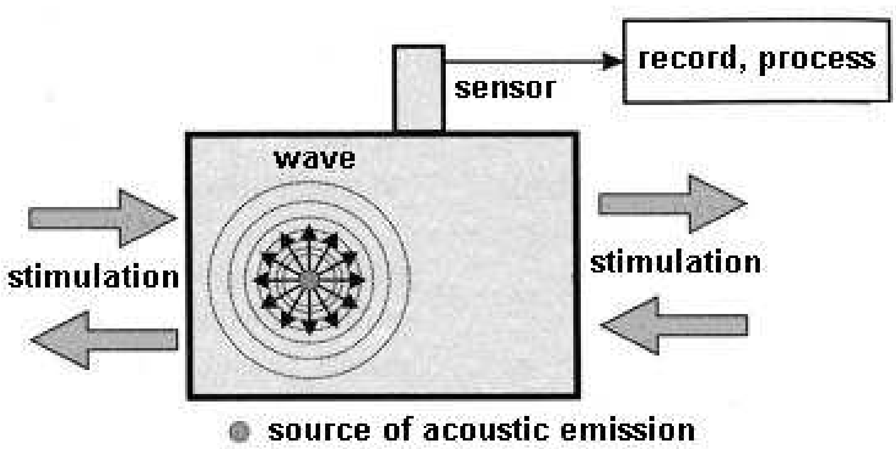

Figure 2: Rise and propagation undulation at a matter's acoustic emission (Mazal et all, 2005)

2. EXPERIMENTAL SETUP

Temperature measurement during concrete setting was made with thermal resistors NTC K164NK022. Two sensors detected room temperature and three sensors were included within the concrete specimen. Two specimens were tested simultaneously. A block diagram of the experimental set-up is shown in Figure 3 and its photo is in Figure 4.

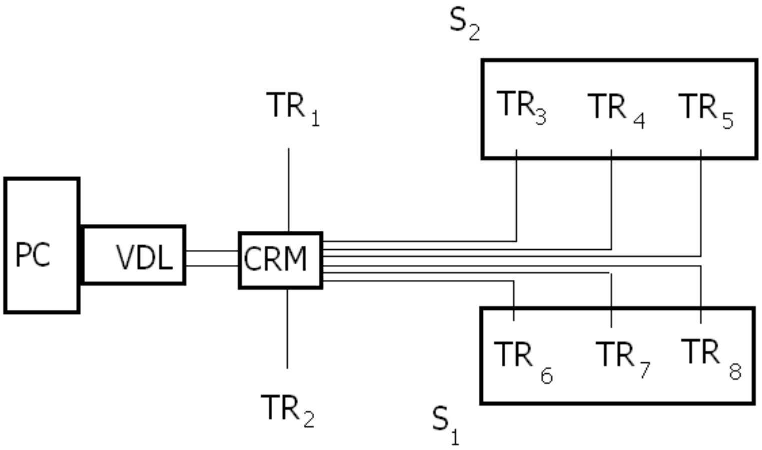

Figure 3: Block diagram of set-up experiment (PC – computer, VDL – Virtual Data Logger, CRM – Channel Relay Multiplexer, S – specimen, TR – Thermal Resistor) (Bilek at all, 2007))

Figure 4: Experimental set-up of measuring

3. DISCUSSION

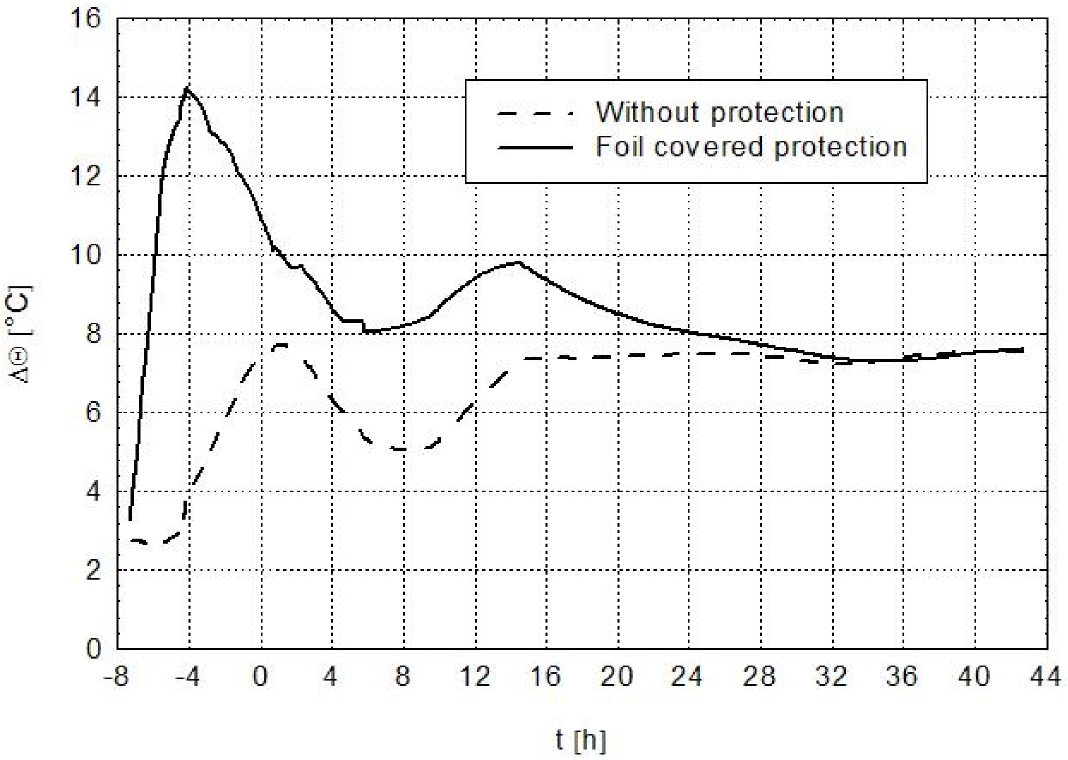

Figure 5: Temperature history

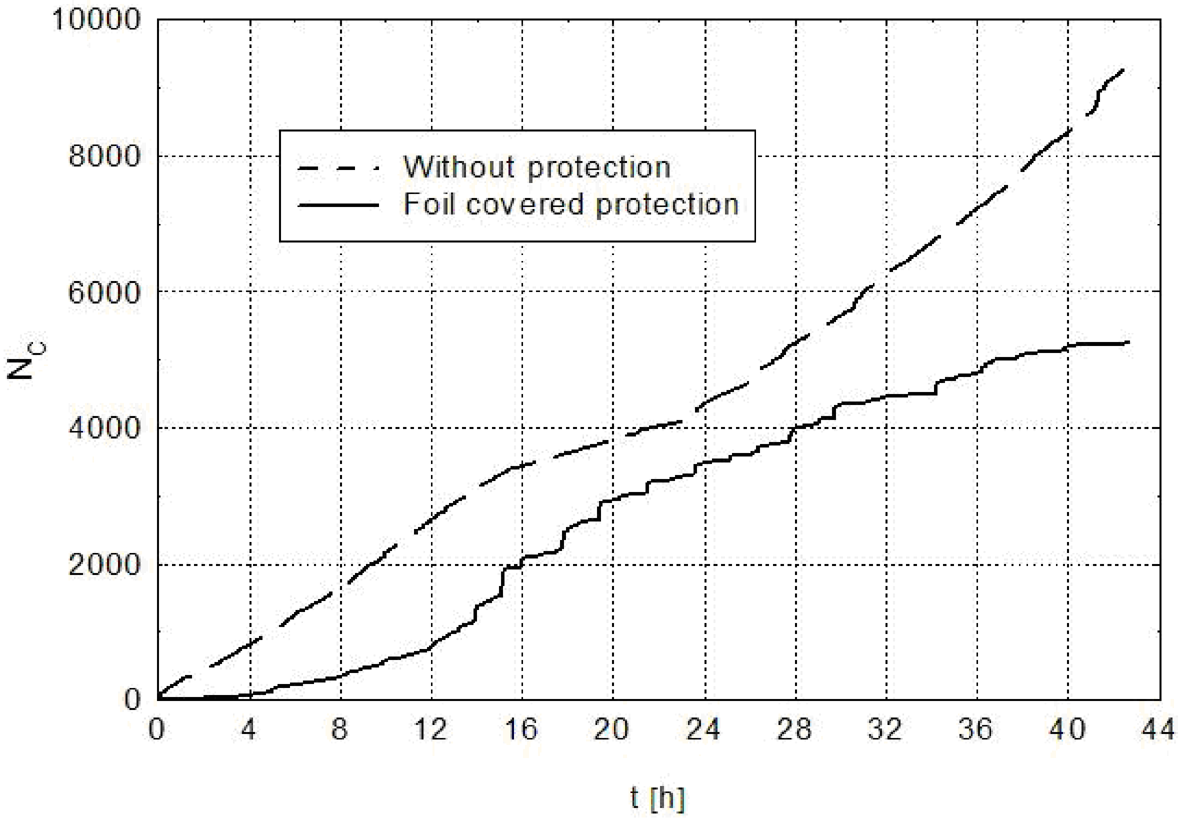

Figure 6: Accumulating the counts from all the detected emissions

Temperature history of observed specimens is of interest for up to a day. One sample was sealed by PE foil to avoid any water exchange with the environment; the beam was cured without any water exchange prevention. (Mazal P. et all, 2007)

For acoustic emissions, the defect produces its own signal as it grows, and this signal is detected by a remote sensor. This is fundamentally different from most non-destructive methods, so the acoustic emission has a unique set of capabilities and limitations. Properly used in suitable combinations with other methods, the acoustic emission brings major cost savings and added effectiveness to durability.

4. CONCLUSION

Volume variations of concrete structures are connected with autogenous shrinkage and changes in humidity. The interesting part of concrete setting is temperature observation with a dependence on time. The application of the acoustic emission method to determine cracks in structures is the next step of this experiment.

A new technique of recorded signal analysis has also been applied. (Smutny J. et. all., 2001).

In future, some interesting methods to describe the hardening processes such as impedance spectroscopy, impact echo, non-linear ultrasonic spectroscopy etc. as well as non-traditional analysis will be applied. (Korenska M. et. all., 2001,2008; Ficker T., 2008; Pazdera L. et all, 2007)

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Technical Notes on Participation on balloting process of ASTM International

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Introduction

ASTM International is one of the largest voluntary standards development organizations in the world. It is a trusted source for technical standards for materials, products, systems, and services. There are over 130 ASTM technical committees covering diverse industry areas ranging from metals to the environment. The author of the technical note is a voting member of five of them. They are:

- Committee C09 on Concrete and Concrete Aggregates
- Committee D04 on Road and Paving Materials
- Committee D18 on Soil and Rock
- Committee D35 on Geosynthetics
- Committee E07 on Non-destructive Testing

Above mentioned committees balloted about 394 documents, see Table 1.

	Number of Ballots				
Ballot	Committee C09	Committee D04	Committee D18	Committee D35	Committee E07
1/09	49	45	25	24	39
2/09	28	3	11	14	30
3/09	38	23	16	8	-
4/09	21	1	11	-	-
5/09	1	3	-	-	-
6/09	4	-	-	-	-
Sum in the Committee	141	75	63	46	69
Total Sum in Specified 5 Committees	394				

Table 1: Number of Ballots in Specified Committees

The technical note would like to inform about the new standards or their revisions in the mentioned committees in 2009.

Committee C09 on Concrete and Concrete Aggregates

The committee was balloting about new standards or revisions of test methods for e.g. resistance to degradation of large-size coarse aggregate by abrasion and impact in the Los Angeles machine, for bond strength of adhesive systems used with concrete as measured by direct tension, for self leveling mortars containing hydraulic cements, for slump flow of self-consolidating (compacting) concrete, for passing ability of self-consolidating concrete by J-ring, for air content of freshly mixed concrete by the pressure method, for flexural strength of concrete (using simple beam with third-point and center-point loading), for microscopic determination of parameters of the air-void system in hardened concrete, for electrical indication of concretes ability to resist chloride ion penetration, for water-soluble sulfate in soil, for restrained expansion of shrinkage-compensating concrete, for potential alkali reactivity of cement-aggregate etc.

In the same time the Committee was busy with preparation of specifications, such as for coal fly ash and raw or calcined natural pozzolan for use in concrete, for fiber-reinforced concrete and shotcrete, for chemical admixtures for concrete, cold-weather admixture systems, for packaged, dry, combined materials for mortar and concrete, ready-mixed concrete etc.

The committee was voting about many guides, practices and other documents regarding to concrete and concrete aggregate.

Committee D04 on Road and Paving Materials

Asphalt and bituminous materials have taken large part of the committee effort. The test methods, specifications and other documents referred to them. Some documents were targeted to base and subbase materials and their testing.

Committee D18 on Soil and Rock

Besides test methods, guides and other documents very big effort of the committee was aimed to practice such as for minimum geospatial data for an abandoned mine land problem area, for minimum geospatial data for underground coal mining extents, for description and identification of soils visual-manual procedure, for classification of soils and soil-aggregate mixtures for highway construction purposes, decontamination of field equipment used at low level radioactive waste sites.

Committee D35 on Geosynthetics

Needed test methods, guides, practices and other documents was discussed in the committee, e.g. for trapezoid tearing strength of geotextiles, for strength of sewn or thermally bonded seams of geotextiles, for measuring mass per unit area of geotextiles, for static puncture strength of geotextiles and geotextile-related products using a 50-mm probe, for determining tensile properties of geogrids by the single or multi-rib tensile method, for abrasion resistance of geotextiles sand paper/sliding block method, for determining filtering efficiency and flow rate of the filtration component of a sediment retention device using site-specific soil etc.

Committee E07 on Non-destructive Testing

Radiographic and radioscopic methods were widely discussed in the committee. Besides them guides, practices and test methods aimed to other NDT methods where balloted, such as for the pulsed longitudinal wave ultrasonic examination of metaland metal alloy production material, for electromagnetic eddy-current examination of copper and copper-alloy tubes, for quality management systems for nondestructive testing agencies, for terminology for nondestructive examinations etc.

Summary and Acknowledgement

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Instructions to the autors

1 GENERAL GUIDELINES

Papers based on accepted abstracts and prepared in accordance to these guidelines are to be submitted through thejournal's web site www.transportsciences.org. All papers, using Microsoft Word2000 (or newer) are limited to a size *oe* at least 4 and no morethan 8 single-spaced pages on A4 paper size (297 mm X 210 mm), inc1uding figures, tables, andreferences and should have an even number oepages. The paper's top, bottom, right and left margins must be 2.5 cm. No headers, footers and page numbers should be inserted.

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The title of the paper must be in title letters, Times New Roman, font size 16, and a1igned left. Use more than one line ifnecessary, but always use single-line spacing (without blank lines). Then, after one blank line, aligned left, type the First Author's name (first the initial of the first name, then the last name). If any of the co-authors have the same affiliation as the first author, add hislher name after an & (or a comma ifmore names follow). In the following line type the institution details (Name of the institution, City, State/Province, Country and e-mail address of a corresponding author). Ifthere are authors linked to other institutions, after a blank line, repeat this procedure. The authors name must be in Times New Roman, regular, and font size 12. The institution details must be in Times New Roman, *ita/že*, and font size 10.

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