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ЗАЛІЗНИЧНА КОЛІЯ ТА АВТОМОБІЛЬНІ ДОРОГИ

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REVIEW OF THE MODERN BALLASTED RAILWAY TRACKS' SUBSTRUCTURE AND FURTHER INVESTIGATIONS

Purpose. The authors' aim is to summarize the results of relevant international publications and, based on these, to give a comprehensive review about the modern ballasted tracks' substructure. **Methodology.** This article is a start of a PhD research, which means it was proceeded by a secondary research. At first, the substructure and its protection layers were summarized, after that the geosynthetic cementious composite mat materials, especially the Concrete Canvas are discussed. **Findings.** The experiences of the geosynthetics' and other protection layers' functions, show that a possible using of the GCCM (geosynthetic cementious composite mat) under the ballast can be a good solution for renewing short sections in the railway tracks. **Originality.** One of the authors – namely Balázs Eller – is a PhD student at Szechenyi Istvan University in Gyor (Hungary). His research topic is the reinforcement possibilities of railway substructure with the usage of special (mainly cement-bonded) layers. This article was written to collect and summarize the up to date knowledge related to modern ballasted railway tracks' substructure to be able to determine the following research ways and possibilities at this topic. The research plan will be sentenced in the near future, as well as the required laboratory and field tests will be prepared. **Practical value.** As expectation, after having executed the related research, the advantages and disadvantages of GCCM layers in the railway substructure will be able to defined, as well as factual deterioration process can be determined related to the ballasted tracks and their geometrical stability.

Keywords: substructure; subgrade; ballasted track; protection layer; concrete canvas

Purpose

The aim of this paper to summarize the experiences about the connection between the substructure and superstructure, and the railway protection layers at relevant international publications to make a comprehensive review about the adequate technologies of nowadays. After that a new possibility is being showed, which could help to reduce future maintenance costs. This paper deals with the ballasted tracks, because this is what was established almost in Hungary, and because of the weaker and flexible base, the substructure fouling is more significant here.

Methodology

The basis of this paper is the research in science education, and study current state-of-the-art technologies. The authors studied the different materials, the investigations with them and their behaviour from usability aspect. Both laboratory and in situ tests are being studied. The different technologies are being compared, for study the better and cost effective ways to use.

The railway substructure

In general

The degradation process of the railway track is a natural process. The ageing of the different types and different materials of elements is not the same. For example, from a bad (insufficient) rail welding or rail joint, there can be increased dynamical ef-

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fect which leads to more pumping effect and contaminated ballast. From another aspect, the consequence is the same if the problem comes from the weak soil properties or inadequate drainage. In this complex system, all the elements influence all the other elements. The degradation has to be maintained, but while a welding or a rail can be changed relative easily, the subgrade could only be renewed after the established of the whole superstructure. So the superstructure of the railway needs permanently and adequate support from the subballast, subgrade.

If the substructure has not got enough bearing capacity or it has got weak soil mechanical properties, a new protection layer is needed. Otherwise, the many speed limits that caused by the obsoleted faults, need more excess energy that could cost billions in every year [15], furthermore the maintaining of these faults also costs a lot. If the axle load is increased by 2.5 tons, the total maintenance cost increased by 4.2% too [28]. If the substructure has not got enough bearing capacity and other appropriate soil mechanical properties, soil replacement or new protection layer is needed. That improves the bearing capacity, drainage and other significant tasks that are indispensable.

On the other hand, the ballast layer is the other important element because it connects to the substructure and distributes the load to there. Ballast and subballast contribute to protect the subgrade from overstressing [39]. However, subballast, which is always needed, is preferred for completing the total granular layer thickness beyond the minimum ballast layer thickness required for fulfilling the other ballast functions. Thanks to this, the track deformation is closely related to the quality of ballast. Fouling causes accumulation of fines between ballast particles and consequently increases the permanent deformation within the ballast layer and results in increased surface deviation of railway track [8]. Fouling can also inhibit drainage and may lead to deterioration in the mechanical properties of the medium. In the worst case, mud pumping effect occurs. If the fine particles from the subgrade is mixed with the ballast, the way out of the water is ended (Fig. 1). This can be a straight way for a water pocket (or in other words: ballast pocket or water bag) to being formed. This problem can be hard to solve, because the simple ballast exchange is not enough, very ineffective [36].

Fouling

The major causes that may contribute to the development of subgrade problems can be categorized into three groups [29]:

- load factor,
- soil factor,
- environmental factor (soil moisture, soil temperature).

There are two types of loads in the railways:

- the deadweight of the railway structure,
- the dynamic loads of the traffic.

The deadweight occurs less problem than the dynamical effects, but a badly constructed or designed embankment could cause stability or shear failure problems. The dynamical traffic loading is a repeated, cyclic loading. The effect of the static and dynamic loads are different on the subgrade, even if the magnitude of the axle load is the same [29].

The soil factor means soils with poor (mechanical and geotechnical) characteristics, like the fine graded soils (clay and silt). In these soils, the moisture content could occur change in the strengthening and the permeability. Furthermore, the dynamical loads on the weak soil with large moisture level occur higher and faster (or in other words: more extensive) degradation on the plane of the subgrade. Besides that, the coarse-grained materials drain well, so the moisture in the subgrade is also lower.

The environmental factor contains the earlier mentioned soil moisture and the temperature, too. The water comes by infiltration from the surface and from the groundwater, as well. The moisture level in the substructure is different in every season. If the temperature is below zero, the freeze can cause more problems and faster degradation process. The frost sensitivity depends on the capillarity, the degree of irregularity and the sum of the multiplied frost days [30].

The adequate drainage is another important part that needs well-formed substructure crown (i.e. top surface), appropriate material for water spillage and (relative) clean ballast. For a longer life-time, protection layer is recommended which can guarantee the drainage and the bearing capacity, as well.

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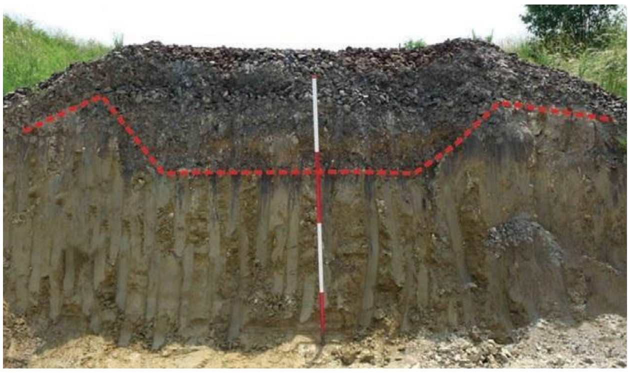

Fig. 1. The fouling of the ballast and the substructure [42]

Improving technologies

The generally requirements related to the sub-ballast and the protection layer on it [40, 44]:

- stress reduction,
- separation (preventing the mix of the fine particles and the ballast),
- drainage,
- filtration,
- increase bearing-capacity (it is very important according to the growing axle loads),
- frost protection,
- damping vibration.

These requirements are not featured on every protection layers. It can be talked about more possibilities that are used for various work or work steps, because of their different thicknesses, material properties or the technological instructions. Essentially, the best protection layer can solve the perfect separation and drainage functions. The technologies of the mechanical life are being developed continuously, in this way the protection layers are being developed also.

The most mentionable protective layers are:

- coarse grained materials, sandy gravel, etc.,
- geosynthetics (geogrid, geotextile, geocomposit, geomembrane),
- asphalt concrete layer,
- extruded polystyrene (XPS) foam layer.

In this paper only the extraordinary technologies are being discussed.

Geosynthetics

The application of geosynthetics is technological solution that used in the building industry to reinforce structures, create the appropriate drainage or other problems to solve. There are many types of geosynthetics with many functions that can be applied in many different ways. The most important geosynthetic products are the following:

- geotextile (separation, filtration, dewatering in the level of the textile),
- geogrid (reinforcement),
- geocomposite (combined tasks),
- geomembrane: dewatering, separation.

According to [23], if any type of geosynthetics are laid in the fresh or the recycled ballast, the settlement and the degradation will be decreased, however the fresh material has always better characteristics than the recycled ones. The most recommended variation, if adequate chosen geocomposite (e.g. geogrid + geotextile) is being laid, because it increases the bearing capacity while the separation function also happens.

Geotextiles

Because of the many producers, there are many types of geotextiles. The classical usage of these to reduce the settlement in the embankments and increase the slope stability [26]. With geotextiles, significant increasing of bearing capacity is not existed [45]. In railway construction, geotextiles are a good solution to separate the fine particles of the subgrade and the ballast's particles. On the other hand, in [35] was described that if the geotextile is being installed in the embankment, the depth should be between 200-300 mm below the sleeper base and until the ballast spreading tamping is prohibited.

The experimental study [41] describes the filtration of the geotextiles. It is turned out that the filtration is very influenced by the vertical or horizontal orientation of the geotextile. The best filtering characteristics can be achieved with a well-graded soil. On the other hand, it has «worth results for the configuration consisting of a vertical filter filtering a horizontal flux of clayey sludge».

Because of their synthetic base, the geotextiles have very long lifetime which helps to reduce the life time cost. In [35], experiences showed from an American railway track which influenced by very physically harsh environment, that the geotextiles are still showing excellent durability after 18 years of service life. At the railways, where the track diagnostics are continuous, at many cases the geotextiles can get an aluminium sensor strip, for example in every 5 meters (Fig. 2.) [18]. These aluminium strips are detected by the georadar, so after an analysis, experiences can be drawn about the

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thickness of the layers, the deformations of the substructure etc., which help in the further maintenance designs [19, 20].

Fig. 2. Geotextile with radar detected aluminium strip [18]

Geogrids

The geogrids are synthetic nets for strengthening a soil structure or the railway ballast. There are monoaxial, biaxial, triaxial (Fig. 3.), etc. geogrids. The first is oriented in just one direction, the second is oriented into both perpendicular main directions. The principle of the triaxial geogrid is that the triangular shapes can take the load from any direction. Thanks to this, it has the highest the reinforcement effect [9]. The better geogrids are evolved by welding-thawing, because the orientation of the loads passes through the intersections of the geogrid. In these intersections the tensile strength is nearly the same like at the crossings. These are called rigid intersections.

Fig. 3. Geocomposit from Triax geogrid and geotextile [34]

These have separate function and thanks to their formation, the bearing capacity is being increased, too. On the other hand, there is no filtration, and it has no effect on drainage. Laboratory tests have been conducted, which are related to such application of geogrids in railway constructions where the subgrade/subsoil was not reinforced, but the ballasted bedded railway superstructure was. In these structures geogrids were placed under – and in some cases into – the ballast material. It was expected that the geogrid would clamp particles of ballast material at the bottom of the ballast; in this way the railway track would be floating in the ballast material and exposed to dynamic effects. For other vibrations the structure would be more resistant to the deformation of the tracks. This phenomenon is the so-called interlocking effect (Fig. 4.) [43].

The interlocking effect has three different zones:

- unconfined zone,
- transition zone,
- fully confined zone.

There is the unconfined zone in the top zone where the reinforcement effect is not considerable. The middle zone is a transition zone. The interlocking effect is increasing in non-linear way. The last, lower zone is directly at the geogrid, which is the fully confined zone. On the upper 10 cm above the plane of the geogrid the interlocking effect is at maximum value. The particles can not move easily, so the internal shear stress resistance is really high [15, 43]. Furthermore, based on the results of the presented multi-level shear box tests it can be seen that a geogrid with a correct aperture size can radically increase the inner shear resistance of the soil mass with an influence even 20 cm from the level of the reinforcement layer due to the effective interlocking effect [15]. This aperture size of the geogrid is very important if the best effective reinforcement should be reached. For a max. 50 mm size ballast the best aperture size was 60-80 mm [4]. A part of this is tried to confirm in [9], where "SmartRocks" were used in the ballast box to monitor individual ballast particle movement. In this experiment, ballast box with and without geogrid was investigated under 500 cycles, and the result of the comparison was that the "SmartRock" in the box without geogrid had much more noticeable movement and rotation were noted.

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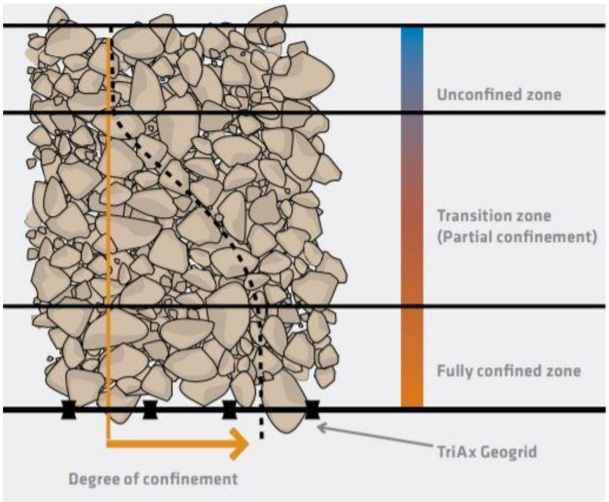

Fig. 4. The interlocking effect in the ballast [43]

In [3] also a large-scale direct shear testing was made under low normal stresses. A generalised empirical formulation was developed from the measurement of the interface shear resistance between subballast and the different types of geosynthetics. Although, the results showed that the different types of geosynthetics provide different interface shear resistance values.

In this way, in the ballast floating, dynamic loaded railway track will geometrically be more stable and more resistant against evolving of settlement faults. Stresses arise in the ribs and junctions of the geogrid due to vehicle load, the geogrid can offer resistance against these stresses with tensile strength and low strain. Tensile strength should be adequate high, but failure strain should be acceptable low, because of the load bearing capacity with low strain. The latter property is important because the geogrid should bear adequate magnitude load [21].

On the other hand, literature [4] described that the reinforcement effect is larger if the subgrade had soft soil, than stiff one. Nevertheless, based on [15] the ballast particles can connect to the geogrid the best way if there is sandy layer below the geogrid, because it helps the indentation and save the lower geotextile if it is existed.

Geocomposite

The geocomposite is two or more geosynthetics that are attached together (Fig. 3). The combinations can be made from all earlier mentioned geosynthetics. For example, the geogrid and the geotextile make correct geocomposite, cause the geogrid provides more bearing capacity, while the geotextile provides the better separation, filtration, etc. Because of the geogrid aperture size, the mud could mix with the ballast, but the geotextile can prevent that. The attach (assembly) of the materials can be in factory or at the construction site too [45, 34]. This structure called sandwich structure.

According to the [23] research's results, the geocomposits occurs less vertical settlement in the recycled ballast, even less than the fresh ballast which does not contain geocomposite. Furthermore, the brakeage index was also decreased like the fresh ballast. These results are considerable consequence at the railway maintenance, because it can make longer the life-time of the ballast and the whole superstructure.

Geomembrane

The geomembranes are continuous, elastic and water tight synthetic plates which ensures very good drainage. The tensile strength is also appropriate. The most important function of the geomembrane is the perfect drainage, because the water sensitive substructures can be defending from the rainfalls, and the moisture content in the embankment could be effected only by the capillarity, and the volume change of the soil could be minimized [27]. The particles of the ballast can tear the interface of the geomembrane so a min. 10 cm coarse-grained layer is needed above the plane. The thickness is normally between 0.15-3.00 mm [45].

Other protection layers

Asphalt protection layer

Asphalt concrete is an alternative or supplement to sand/gravel subballast materials, but the economics will probably limit asphalt to special cases [39]. It is a good alternate solution to save the homogeneity, increasing the bearing capacity and protecting the crown of the substructure (Fig. 5). The technology is also a good solution in ballastless tracks. Because of its elasticity, the supporting is not so rigid like at the concrete slabs.

The previous experiences showed that this type of protection layers can be fully adequate at the forming requirements of the railway track. The bearing capacity and the separation are solved equally. At case of soils that have low E_2 modulii, considerable bearing-capacity growing happens, that is thanked to the better distribution of trains' static and dynamic loads. The bituminous binders

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are perfectly watertight and separated, so the embankment's soil and the ballast do not connect to each other. It prevents many unfavourable events. In this case the fine materials cannot pump up to the ballast so the drainage is not blocked [45]. According to Peter Veit, who is an expert of the life-time cost research, the need of the leveling-lining-tamping (LLT) works were delayed by 67%. From the connection of life-time cost and the working life, the lifetime of the superstructure was increased by 17% [37]. Furthermore, the noise levels of slab tracks are higher than tracks on asphalt pavement under train running [31]. The various hot mix asphalt is also good in damping vibrations [6, 45].

With this technology, there are very convincing international experiences from Germany, Italy, Spain, Japan, USA, etc. [10]. In Germany, there are many technological solutions in the creation of a hot mix asphalt based railway track like system Sato, Getrac, etc. [16, 17], which give very good solutions at high speed railways. These technologies are in ballastless tracks. Investigations in literature [17] showed that at the Getrac system the asphalted section has 50% better results than the control section from the aspect of longitudinal and transversal movements. The continuous line walks and investigations showed that the track has no sign of fatigue and the connective cylinders were in good condition. The maintenance experiences were positive, too. In the case of unexpected failures like the indentation, it was easy to access the faulty part. It was enough to elevate the track, because there is no ballast to dredge it down.

In the literature [2] asphalt and concrete base were compared to each other under turnouts, and the asphalt layered turnout showed better results, because it is elasticity. The article [32] described that in Japan the asphalt is used in ballastless and ballasted tracks, too. In ballasted tracks 50 mm of asphalt subballast is being used, while in every other country 100-120 mm are the minimum thickness. This solution is applied for 30-40 years. In Hungary the experience of using 60 mm of asphalt layer is inadequate, the protection layer cracked soon. The solution of this contradiction has to be searched at the foundations of these layers. In the USA until 2008, quality investigations were made at eight sections between the age of 12 and 29. The measurements were repeated in every 2-3 years, so the little failures and fatigue signs can be seen easily. By these tests the fatigue life-time of the asphalt was proved scientifically and officially. It was seen also squarely that the failures of the roads do not exist under the ballast [38].

Fig. 5. Ballasted track with asphalt subballast [10]

Summarized, it can be noted that the application of the asphalt protection layer can be very multiple. The adequate support and the perfect dewatering provide the sustainability; the increasing of the axle loads or the velocity in the substructure aspect.

Another important aspect is the changing climate that results short and large intensity rains. This factor will be accentuated in the sooner future, because the rain damages more the top of the substructure. The asphalt layer gives perfect drainage, so it can be a very efficient solution [10].

XPS polystyrene slabs

Another technology which is used because of its insulation ability is the XPS polystyrene slab.

Extruded polystyrene (XPS) foam was utilised several times in Finland, Austria and other European countries, too. First of all, the XPS boards has frost protection function, but it has separation and drainage function as well. It has very good insulation properties thanks to its good strength and water resistance, which has to be adequate after the ballast particles' mechanical damages. After 40 years of service life, the materials were examined with sufficent results [33].

This material has high compressive and bending strength. The hydration is negligible, so the frost resistance of the slabs is adequate for their

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application. Because of the long lifetime, the aging and the dry-rotting are not important in this case. The dead load is weak and it makes the polystyrene slabs easily workable. It can be built in the track structure, while the ballast cleaning (screening) machine is working. The boards can move, but with serious technological discipline, the failures can be eliminated. These factors make the expanded polystyrene applicable for the building into or below the superstructure. Previous investigations show that 1 cm thick polystyrene is equal to approx. 10 cm thick original frost protection layer [34].

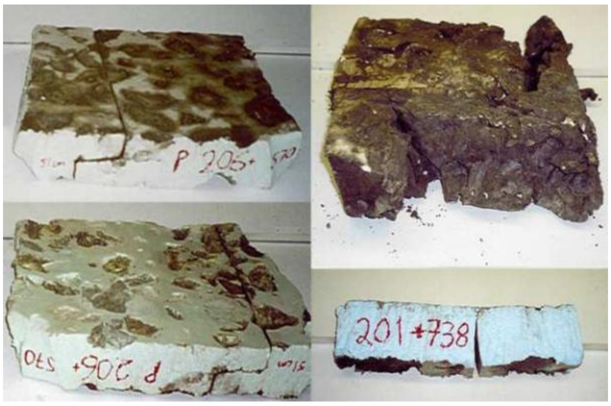

Fig. 6. XPS specimens from the railway track after 5-10 years [33]

Several investigations were made that showed the mechanical damage of the ballast stone was maximum 10 mm (Fig. 6), the compressive deformation was adequate, and the maximum moisture content was 10-12% during their expected service life of 40 years [33]. This material can significantly reduce the frozen depth and frost under the track structure, and compressive degradation was also less under a high-speed railway [11].

Other technologies to use under investigation

The most applied technologies were discussed in the previous chapters. Using the railway experiences of these, the following new ideas are coming.

Nowadays a relative new technology, the under ballast mats (UBM) are being applied which increases the elasticity. Thanks to this, vibration and the secondary noise is being reduced, while the ageing of the ballast particles also decreased [34].

From this, other technologies like this are the geosynthetic cementious composite mats (GCCM). This GCCM and textile reinforced concretes (TRC) are based of using cement impregnated fabric. From functioning aspect, it is nearly the same like the shotcrete, but easier to install, and needs less time for application. These are comprised of the geotextile layers and cement powder [14]. These can be used for many geotechnical applications like ditch covering, retaining walls, soil erosion control, slope protection, etc. [1, 5, 7, 14].

Concrete Canvas

One of these technologies is the Concrete Canvas (CC for short), which was invented by Brewin and Crawford in 2004, in the UK. The types of the product showed in Table 1. The material was utilised like a soft cloth in civil (slope protection, a trackway for vehicles, pedestrians or protection layer for pipe and lining) and in military engineering (prefabricated shelter) [18, 43]. The CC is barely investigated in the professional literatures yet; the only varied investigations were showed in [1, 7, 13, 22, 24, 25].

Table 1

The types of the Concrete Canvas [12]

Product type	Concrete thickness (mm)	Bulk roll size (m^{-2})	Roll width (m)	Mass (unset) ($kg*m^{-2}$)	Concrete mean density (unset) ($kg*m^{-3}$)	Change in density when set (%)
CC5	5	200	1	7	1430-1540	+30 to 35
CC8	8	125	1,1	12	1430-1540	+30 to 35
CC13	13	80	1,1	19	1430-1540	+30 to 35

As it is already discussed, Concrete Canvas is a geosynthetic cementitious composite mat and barrier for use in a range of geotechnical applications, with minimum 50 years' life time [12]. It is a flexible cement powder impregnated fabric (Fig. 7) that hardens on hydration to form a thin, durable, water proof and fire-resistant concrete layer. The mat is easy to install, because the material in non-bound form is easy to lay and spray by water. The only problem to solve is the access to water, if the work area is difficult to access. At non-bound form its density is 1300-1500 kg/m^3 because of the dry cement powder. After the spraying with water, the final density is around 1700-2000 kg/m^3 which is nearly 70-80% of the ordinary concrete (2200-2400 kg/m^3) [5, 13].

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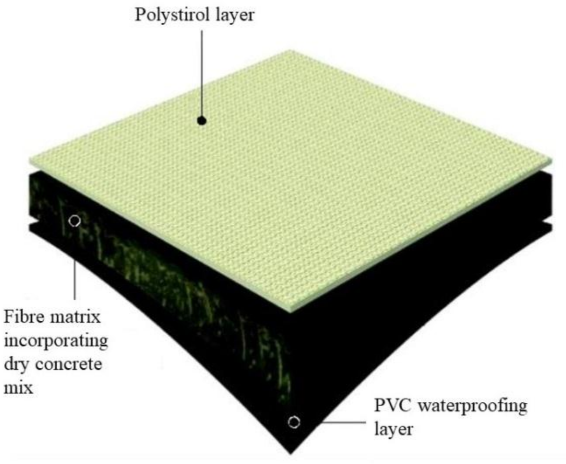

Fig. 7. The structure of the Concrete Canvas [12]

Similar material is the shotcrete layer. Compared to this, the CC is not just faster (shorter construction) and easier to install, it is more cost-effective too, and the environmental impact is also reduced [7].

As described in the literature [22, 24, 25] the mechanical strength and volume stability depend on the geometric patterns of the material, the type of fibre and the type of the cement matrix.

The effective usage was examined in [7] with good results. Comparing to the shotcrete, the CC's properties were faster and better or nearly the same, so it is more suitable to be used for slope protection. On the other hand, the layer is protecting the slope from rainfall, so the stability of the slope also in safe. In [1] the application design in soil reinforced structure was discussed. The whole construction process is considerably shorter, because after the CC wall reached the 70% of the final strength. It is nearly 24 hours [5]. After the water spraying the backfill can be filling back in few days.

Application in railway layer structures

The CC may also have potential application as a rigid railway protective layer. Summing the advantages of the geosynthetics, it is seen that their functions in the railway structure is nearly the same what the geosynthetic cementitious composite mats can provide under the ballast. If it is used under the superstructure, it can function like geotextile, geomembrane and geogrid at the same time. Furthermore, if the mat hardens after that the ballast was already replaced, the deformed mat will become rigid while taking the shape of the particles. Thanks to this, it is hypothesized that interlocking effect is being achieved – more or less.

Further investigations will be made, to confirm the usability of the GCCMs, particularly the CC under railway loads. The examination of Concrete Canvas' (three-point static and dynamic bending laboratory tests) are in progress. If it is used under the ballast, the mat can have deformed before the rigid state. The technology could be used at local failures, while the ballast is being exchanged (screened, cleaned), even by manual or machine ballast replacement technologies.

In the case of 210 kN axle load, approximately 10 N/cm^2 could be the loading on the surface of the hardened CC [10, 34]. The question that has to be investigated is the CC's behaviour in the railway structure, because the significant loads are transmissioned from the ballast particles dynamically. On the rigid CC layer, the loads would be distributed in larger zone, so the loads could be absorbed easier.

If the CC would be used with XPS polystyrene slabs, the dynamical impacts could be more absorbed, so the CC layer could be more in safe. At this solution, the thickness of the frost protection layer could be reduced, while the structure could get extra bearing capacity by the rigid CC layer. This version could be more effect at the local failures.

Findings

The adequate support is a fundamental part of the railway tracks. Because of it, there are many good technologies to use, while others are under development. The authors' main purpose is to investigate the GCCM technology, how it can be applied on the railway substructure to earn more life time to the sub- and superstructure.

From the experiences which was drawn in the article, it is hypothesized that the CC and other GCCM layer could be even or better than the geosynthetics, and the local track failures (moisture problems in the substructure, muddy ballast, etc.) could be solved.

Originality and practical value

As the authors introduced, there are a lot of possible technologies that are or can be adequate for improving the insufficient railway substruc-

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tures, i.e. solve some of the problems related to e.g. railway embankments. These problems can be load bearing capacity problems due to dewatering or material (soil) property inadequacies (e.g. density, strength, stress state, shearing characteristics, etc.). These problems have to be solved.

One of the authors – namely Balázs Eller – is a PhD student at Széchenyi István University in Győr (Hungary). His research topic is the reinforcement possibilities of railway substructure with the usage of special (mainly cement-bonded) layers. This article was written to collect and summarize the up to date knowledge related to modern ballasted railway tracks' substructure to be able to determine the following research ways and possibilities at this topic. The research plan will be sentenced in the near future, as well as the required laboratory and field tests will be prepared. As expectation, after having executed the related research, the advantages and disadvantages of GCCM layers in the railway substructure will be able to defined, as well as factual deterioration process can be determined related to the ballasted tracks and their geometrical stability.

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ОГЛЯД НИЖНЬОЇ БУДОВИ СУЧАСНИХ ЗАЛІЗНИЧНИХ КОЛІЙ З БАЛАСТНИМ ШАРОМ І ПОДАЛЬШІ ДОСЛІДЖЕННЯ

Мета. Основна мета цього дослідження – узагальнити результати відповідних міжнародних публікацій і на їх основі дати вичерпний огляд нижньої будови сучасних залізничних колій з баластним шаром. **Методика.** Ця стаття є початком аспірантського дослідження; відповідно існує друга частина дослідження. Спочатку автори підводять підсумки досліджень про нижню будову колії та її захисні шари, після чого аналізують матеріали геосинтетичного цементного складеного мата, особливо – бетонне полотно. **Результати.** Досвід використання функцій геосинтетичних та інших захисних шарів показує, що можливе використання геосинтетичного цементного складеного мата (ГЦСМ) під баластним шаром може стати хорошим рішенням для поновлення коротких ділянок залізничних колій. **Наукова новизна.** Один з авторів, а саме Балаш Еллер, є аспірантом в Університеті Іштвана Сечені у Дьєрі (Угорщина). Тема його дослідження – можливість зміцнення нижньої будови залізничної колії з використанням спеціальних (переважно цементних) шарів. Ця стаття була написана для збору та узагальнення нових знань про нижню будову сучасних баластних шарів залізничних колій, щоб можна було визначити наступні шляхи та можливості дослідження цієї теми. План досліджень буде сформульовано найближчим часом, також будуть підготовлені необхідні лабораторні та польові випробування. **Практична значимість.** Як і очікувалося, після проведення відповідних досліджень можна буде визначити переваги й недоліки використання шарів ГЦСМ у нижній будові залізничних колій, а також визначити фактичний процес зносу, пов'язаний із баластними коліями та їх геометричною стабільністю.

Ключові слова: нижня будова колії; земляне полотно; колія з баластним шаром; захисний шар; бетонне полотно

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ОБЗОР НИЖНЕГО СТРОЕНИЯ СОВРЕМЕННЫХ ЖЕЛЕЗНОДОРОЖНЫХ ПУТЕЙ С БАЛЛАСТНЫМ СЛОЕМ И ДАЛЬНЕЙШИЕ ИССЛЕДОВАНИЯ

Цель. Основная цель данного исследования – обобщить результаты соответствующих международных публикаций и на их основе дать исчерпывающий обзор нижнего строения современных железнодорожных путей с балластным слоем. **Методика.** Данная статья представляет собой начало аспирантского исследования; соответственно существует вторая часть исследования. Сначала авторы подводят итоги исследований о нижнем строении пути и его защитных слоях, после чего они анализируют материалы геосинтетического цементного составного мата, в особенности – бетонное полотно. **Результаты.** Опыт использования функций геосинтетических и других защитных слоев показывает, что возможное использование геосинтетического цементного составного мата (ГЦСМ) под балластным слоем может стать хорошим решением для обновления коротких участков железнодорожных путей. **Научная новизна.** Один из авторов, а именно Балаш Эллер, является аспирантом в Университете Иштвана Сечени в Дьере (Венгрия). Тема его исследования – возможность укрепления нижнего строения железнодорожного пути с использованием специальных (преимущественно цементных) слоев. Данная статья была написана для сбора и обобщения новейших знаний о нижнем строении современных балластных слоёв железнодорожных путей, чтобы можно было определить следующие пути и возможности исследования этой темы. План исследований будет сформулирован в ближайшее время, также будут подготовлены необходимые лабораторные и полевые испытания. **Практическая значимость.** Как и ожидалось, после выполнения соответствующих исследований можно будет определить преимущества и недостатки использования слоев ГЦСМ в нижнем строении железнодорожного пути, а также определить фактический процесс износа, связанный с балластными путями и их геометрической стабильностью.

Ключевые слова: нижнее строение пути; земляное полотно; путь с балластным слоем; защитный слой; бетонное полотно

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